STUDIES ON THE EFFECT OF MODERN ORGANOPHOSPHATES AND CARBAMATES ON THE REPRODUCTIVE SYSTEM OF *DYSDERCUS CINGULATUS* AND *DIACRISIA OBLIQUA*

ABSTRACT

THESIS

SUBMITTED FOR THE AWARD OF THE DEGREE OF

Doctor of Philosophy

IN

ZOOLOGY

BY

KHOWAJA JAMAL

M. Sc., M. Phil.

DEPARTMENT OF ZOOLOGY
ALIGARH MUSLIM UNIVERSITY
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ABSTRACT

Insects and plants have undergone constant interaction from time immemorable and the struggle between man and insects also began long before the human civilization came into existence. It has continued without cessation to the present time and probably will continue as long as the human race persists. It is because of the fact that both man and certain insect species constantly want same things at the same time. To control these insect pests, man has evolved various methods and the most commonly used technique has been the application of chemicals (insecticides). The use of insecticides against the insect pests is not new, as man very likely employed chemicals for the control of insects before he learned to write. Since then, the magnitude of production of these chemicals is increasing day by day. Presently, the indiscriminate and extensive use of insecticides on one hand solves a problem but on the other hand it creates many crises such as their residual effects, possible hazards to non-target organisms, and most importantly the development of resistance against concerned insecticides. But, in spite of these drawbacks, there is no alternate method to overcome the problem of insect pests and undoubtedly, the use of insecticides is still of the major importance in reducing the insect population. However, these compounds must be administered in such a way as not to interfere with animal food chain or yield persistent residues or develop resistance in target insects. According to WHO (Jacobson and Beroza, 1964) the insect pests are responsible for half of all human deaths and deformities due to diseases. Moreover, insects consume or destroy about a third of every thing that man grows or stores. That is why man has always made considerable efforts to control the harmful insects but it is becoming troublesome day by day. According to Jacobson and Beroza (1964), the economic entomologists and chemists, the designers of the weapons for control of insect pests, find themselves in an embarrassing crossfire. On one side there are farmers demanding more potential insecticides and on the other hand health agencies demand less toxic residues. Thus, keeping in view the demands of the farmers and health agencies, efforts are being made to evolve those insecticides which can fulfil the requirements of both the groups. So, it has become more reasonable to use minimum quantities of insecticides (active ingredient) along with synergists (chemicals which increase the

toxicity of insecticides to several hundred times and are not effective against general insect population) in sublethal doses. It is an established fact that key to the survival of insects is their high reproductive potential. There are voluminous records on the direct but frequently contradictory experimental evidences showing the effects of sublethal dosages of various chemicals on the biology of insects. Furthermore, there is plenty of informations available on the fact that the exposure of insects to various chemicals leads to alterations in fecundity, fertility, longevity as well as immediate mortality. Besides these alterations, the development and maturation of the gonads also get adversely affected when insects survive against the chemical treatment. Most of the studies regarding the anatomical as well as the histopathological effects are concerned with non-conventionally used insecticides (chemosterilants). But in this regard the anatomical as well as histopathological effects of conventionally used insecticides are very scanty. Therefore, the present investigation was planned with a view to know more about the biological effects of some comparatively modern insecticides belonging to organophosphate and carbamate groups. Presently, the insecticides of these two groups are most widely used against insect pests of agricultural crops. These have an edge over insecticides of other nature on account of their credibility of leaving weak stability in the environment and low toxicity to mammals. Hence, it was considered purposeful to study the effect of sublethal doses of some modern organophosphate and carbamate insecticides on the biology and reproductive physiology of *Dysdercus cingulatus* (Fabr.) and *Diacrisia obliqua.* These two species belong to two different orders with different metamorphic conditions. The former species is hemimetabolous (hemipterous) and cosmopolitan in nature. Besides cotton, the nymphs and adults also feed on malvaceous plants (sambhal,lady finger, hollyhock) as well as bajra and other crops of economic value. Whereas the later species *Diacrisia obliqua* presently called as *Spilosoma obliqua* is holometabolous (lepidopterous) and a polyphagous pest, its larvae damage a wide variety of agricultural crops incurring heavy losses of human food resources.

The data in the present investigation reveal that among the organophosphate insecticides, the topical application of the highest selected sublethal concentration (0.002%) of acephate on the 4th instar nymphs of *D. cingulatus* caused maximum

nymphal mortality up to 56% which was 2 and 5% more than caused by the highest selected sublethal concentrations of other compounds of this group i.e. dichlorvos (0.01%) and ethion (0.006%), respectively. Likewise, among the carbamate group, the application of highest selected sublethal concentration of furadan (0.001%) on the 4th instar nymphs showed 57% mortality which was 4% and 8% more than that caused by 0.0025% carbaryl and 0.004% aminocarb, respectively. Similarly, when the treatment was made on the 5th instar nymphs with 0.002% acephate, the average death toll up to the adult emergence was 39% which was 5 and 7% higher than the highest selected sublethal concentrations of ethion and dichlorvos respectively. The topical application of 0.001% furadan on the 5th instar nymphs resulted in 43% nymphal loss up to the adult emergence which was 7 and 8% more as seen by the application of the highest sublethal concentrations of aminocarb (0.004%) and carbaryl (0.0025%), respectively. Furthermore, in the case of *Diacrisia obliqua*, the topical application of highest sublethal concentration of ethion (0.6%) on the 5th instar larvae showed the average larval death of 57% up to adult emergence, whereas, the treatment by that of dichlorvos and acephate (0.4 and 0.1%) had 2 and 4% less larval deaths up to adult emergence, respectively, as compared to ethion. The topical application of the highest sublethal concentration of furadan (0.08%) on the 5th instar caused 63% mortality up to adult emergence as compared to 54 and 59% larval death resulted by the application of highest sublethal concentration (0.25%) of aminocarb and (0.15%) carbaryl respectively. Furthermore, when the topical application was made with 0.6% ethion on the 6th instar larvae of *D. obliqua,* the average death toll up to the adult emergence was 41% which was 7 and 4% more as compared to the treatment made by 0.1% acephate and 0.4% dichlorvos, respectively. Similarly, the treatment of 0.08% furadan on the same instar killed 46% larvae as compared to 44 and 34% death caused by the application of 0.15 and 0.25% carbaryl and aminocarb, respectively. Thus, it is clear from the above findings that among the tested insecticides of both organophosphate and carbamate groups, furadan was the most toxic insecticide for *Diacrisia obliqua* followed by carbaryl > ethion> dichlorvos > aminocarb > acephate.

The data on fecundity and fertility of the females emerged from the treated nymphs/larvae following the topical application of either organophosphate or

carbamate insecticides also reveal inhibitory effects on the reproductive potential of the present insects. Among the present selected organophosphate insecticides, the maximum inhibition in fecundity as well as in fertility of the females was recorded by the highest sublethal concentration of acephate followed by ethion and dichlorvos. Whereas, among the carbamates, the maximum inhibition in the egg production and egg hatching was recorded with furadan followed by carbaryl and aminocarb. The topical application of 0.002% acephate on the 4th instar nymphs of *D. cingulatus* showed 21.83% and 25.86% reduction in the average egg production and egg hatching, respectively. Whereas the topical application of the highest sublethal concentration of ethion and dichlorvos (0.006 and 0.01%) on the same stage caused only 15.25 and 13.08% drop in fecundity as well as 11.11 and 15.08% reduction in fertility of the females as compared to their respective controls. The topical application of 0.001% furadan on the 4th instar nymphs of *D. cingulatus* caused 48.94 and 55.4% fall in the average egg production and egg hatching of the females as compared to their respective controls. The application of highest sublethal concentration of carbaryl (0.0025%) and aminocarb (0.004%) showed only 28.98 and 19.44% reduction in the average egg deposition, whereas, the average hatching of the affected females was dropped by 32.59 and 20.68%, respectively, as compared to the control. Furthermore, the topical application of 0.002% acephate on the 5th instar resulted 86.36% egg laying out of which only 78.95% eggs were hatched. The treatment of the 5th instar nymphs with the highest sublethal concentration of the ethion and dichlorvos (0.006 and 0.01%, respectively) showed 87.1 and 89.1% egg production, out of which 84.9 and 85.8% eggs were hatched, respectively. The topical application of 0.001% furadan on the 5th instar nymphs showed 40.54 and 43.17% drop in the average egg production and hatching, respectively, as compared to the control. Whereas the topical application of 0.0025% carbaryl and 0.004% aminocarb on the 5th instar showed only 22.06 and 15.11% reduction in the average egg production and 23.98 and 19.94% decrease in the average egg hatching of the females, respectively, as compared to the control.

The data on fecundity and fertility of *D. obliqua* females emerged from the 5th and 6th instar treated larvae also revealed that dichlorvos among the organophosphate and furadan among the carbamates caused maximum inhibition in

the egg production and egg hatching in this species. The topical application of 0.4% dichlorvos (OP) on the 5th instar larvae of *D. obliqua* caused 23 and 16% inhibition, respectively, in the average egg production and egg viability of the females as compared to the control. Whereas the topical application of 0.6% ethion and 0.1% acephate on the same instar caused 18 and 14% reduction in fecundity and 13.3 and 11.9% fall in egg hatching of the females, respectively, than the controls. Among the carbamate insecticides, the topical application of 0.08% furadan on the 5th instar larvae of *D. obliqua* followed 39 and 41% fall in egg laying as well as egg hatching as compared to the respective controls. Whereas the treatment of the 5th instar with 0.15% carbaryl and 0.25% aminocarb resulted in 20.9 and 17.0% reduction in average egg production as well as 30.7 and 21.7% fall in egg hatching, respectively, as compared to the control. When the treatment was made on the 6th instar larvae with 0.4% dichlorvos, the reduction in the average egg production and egg hatching was 19.0 and 20.7%, respectively, as compared to the control. However, the treatment of 6th instar larvae with 0.1% acephate and 0.6% ethion resulted in 17.9 and 15.1% fall in fecundity as well as 12 and 15.9% drop in egg viability of the females, respectively, as compared to the control. Among the carbamate insecticides, the application of 0.08% furadan on the 6th instar larvae showed 33 and 38.9% drop in fecundity, whereas, the topical application of 0.15% carbaryl and 0.25% aminocarb on the same stage showed 16 and 10.9% fall in the average egg production as well as 29.5 and 18.3% fall in the egg hatching of the females, respectively, as compared to the control.

The anatomical and histological observations on the gonads following the topical application of the present sublethal concentrations of the selected organophosphate and carbamate insecticides revealed some anomalies. The topical application of all the sublethal concentrations of either acephate, ethion, dichlorvos or furadan, carbaryl and aminocarb on the 4th and the 5th instar nymphs of *Dysdercus cingulatus* and the 5th and 6th instar larvae of *Diacrisia obliqua* did not result in any anatomical or histological deformities in the testes of the adults. The emerged males produced motile sperms which were successfully transferred to the spermathecae of the females during copulation. However, the topical application of the higher sublethal concentrations of all the aforesaid insecticides showed some

anatomical and histopathological deformities in the ovaries of the females which emerged from the treated nymphs/larvae. The nature of damage was almost identical but the degree of damage varied accordingly. The size of the ovary of *D. cingulatus* females as well as the number of oocytes per ovariole reduced remarkably. Moreover, there was inhibition in the development, descent and maturation of the young oocytes in the vitellarium. There was clumping of chromatin in the nuclei of some trophocytes in germinal region. In addition to that, the prefollicular tissue of some ovarioles also showed clumping of chromatin leading to decimation of the tissues. In some severely affected ovarioles, the trophic core as well as nutritive cords became fragile or some times absent altogether.

Like *Dysdercus cingulatus*, the ovaries of *Diacrisia obliqua* females which emerged from the 5th and 6th instar treated larvae following the topical application of sublethal concentrations of the present organophosphate or carbamate insecticides also revealed some important anomalies. Following the application of the higher sublethal concentrations of organophosphates viz., acephate, ethion and dichlorvos and carbamate viz., furadan, carbaryl and aminocarb on the individual 5th and 6th instar larvae, and then following the emergence of the females, the size of the ovaries was reduced significantly. The number of eggs per ovariole was also dropped as compared to the controls. In some cases the lengths of the ovarioles was not uniform, whereas in others, loose arrangement of chorionated eggs at the base of the ovarioles was also evident. In some more severely affected ovaries there was a loop formation in few ovarioles. The size of the bursa copulatrix became comparatively small and less sclerotized. The linear arrangement of both immature and mature eggs were not uniform. The accumulation of yolk protein spheres at the egg cortex was not normal as evident by the different staining property in these eggs. In some ovarioles the ooplasm of the chorionated eggs showed a differential growth pattern including the accumulation the of yolk protein. The staining property of these oocytes showed their young conditions though their accompanying trophocytes were almost exhausted. The follicular cells in some immature oocytes were loosely arranged leaving some space between them. In some more severely affected ovarioles, the number of primordial germ cells in the germarium was less as compared to the control.

Thus, on the basis of the above findings, it is clear that the topical application of sublethal concentrations of acephate, ethion, dichlorvos (organophosphates) and furadan, carbaryl, aminocarb (carbamates) showed promising inhibitory effects on the reproductive potential of both the species (*D. cingulatus* and *D. obliqua*) besides killing more than 50% nymphal as well as larval population. Among the tested insecticides, furadan (carbamate) was the most toxic compound and even a small concentration i.e. 0.001% for *D. cingulatus* and 0.8% for *D. obliqua* gave best results as compared to other tested insecticides at controlled laboratory conditions. Therefore, the use of sublethal concentrations of these tested organophosphate and carbamate insecticides either with some synergists or in IPM (Integrated Pest Management) for the control of *Dysdercus cingulatus* and *Diacrisia obliqua* in field, might be safer in respect to the non-target organisms, residual effects as well as the environmental hazards.

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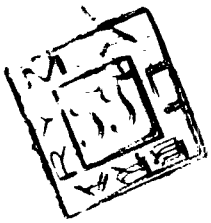

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Date

TO WHOM IT MAY CONCERN

I have the pleasure to certify that the entire contents of the present thesis entitled **"Studies on the effect of modern organophosphates and carbamates on the reproductive system of *Dysdercus cingulatus* and *Diacrisia obliqua*"** were solely investigated by Mr. Khowaja Jamal under my supervision for the award of Ph. D. degree in Zoology, in the department of Zoology, Aligarh Muslim University, Aligarh.

The technical programme, planning and experimental procedures were based on the view to compare the efficacy of certain organophosphates and carbamates, which are presently in use in insect control, on reproduction of *Dysdercus cingulatus* and *Diacrisia obliqua* in order to have a better rationale in their control. Consequently the present observations have provided much useful informations to be employed in the management of the control of these pests.

Mumtaz A Khan

Dr. Mumtaz Ahmad Khan
Professor of Zoology

Dedicated
To
My Bhabhi
(Late) Dr. Rehana Khowaja

CONTENTS

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I express my deep gratitude to Dr. Mumtaz Ahmad Khan, Professor and Chairman (Retired), Department of Zoology, A.M.U, Aligarh, for his supervision, guidance and invaluable suggestions during this investigation as well as continued involvement in the preparation and critically going through this manuscript till the submission of this thesis.

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(Khowaja Jamal)

I- INTRODUCTION

Chemical insecticides have been the backbone of insect pest control since the early 1950s (Dent, 1991) and assumed greater importance in recent years. Among the various methods of insect control, none brings about such prompt and conspicuous relief as that of chemical control. Most studies pertaining to effects of insecticides were concerned with their acute toxicity to insects (Hamilton and Schal, 1990) and emphasis had been on mortality produced rather than on many other effects the chemical may cause (Soderstrom and Lovitt, 1970). Tremendous changes are brought about in the biology of insects exposed to insecticides (Katiyar and Lemonde, 1972). The exposure of insects to insecticides has been shown to cause reduced longevity, fecundity and fertility of survived females as well as immediate mortality. For instance, Hunter *et al.* (1958, '59) found 32-34% biotic reduction in the longevity, fecundity, fertility and survival of progeny in resistant strain of house flies, *Musca domestica* L., treated with DDT or diazinon. Adkisson and Wellso (1962) reported that adult pink bollworm *Pectinophora gossypiella* lived fewer days and produced fewer eggs, surviving low doses of DDT than untreated control. Ridgway *et al.* (1965) reported that feeding of small doses of American Cyanimid CL-47031 to boll weevils, *Anthonomus grandis* greatly reduced oviposition.

Until recently, the effects of sublethal doses of insecticides on insects have received comparatively little attention (Hamilton and Schal, 1990). A fair amount of direct but frequently contradictory experimental evidences has been presented showing the effect of sublethal dosages of various insecticides on the biology of insects. Many reports suggest that sublethal doses of insecticides reduce longevity, fecundity and fertility (Moriarty, 1969; Haynes, 1988; Khowaja *et al.,* 1994). Other reports (Georghiou, 1965; Yokoyama and Pritchard, 1984) indicate that sublethal doses had no effect on longevity and egg fertility. Still other investigators found that insects treated with sublethal doses produced more eggs and lived longer than untreated females (Kuenen, 1958; Ball and Su, 1979; Abd-Elghafar and Appel, 1992; Khowaja *et al.,* 1993).

The effects of an insecticide on insects surviving sublethal doses differ from one chemical to another as well as from one species to another (Abo-Elghar *et al.*, 1972). This effect might be extended to the reproductive and survival potential of the filial generations. Numerous workers have evaluated many chemicals as potential insect reproductive inhibitors (Murray and Bickley, 1964). For instance Speyer (1924), Kalandaze (1927) and Friederich and Steiner (1930) found that the lepidopterous larvae poisoned with arsenicals developed into partial or complete sterile adults. Kissan and Hays (1966) also found triphenyltin acetate and triphenyltin chloride as potential reproductive inhibitors. Similarly, Ansari and Khan (1977) observed a very significant reduction both in fecundity and fertility of the adults *Dysdercus cingulatus* following the application of 35 mg/sq. inch triphenyltin acetate. Styezynska *et al.* (1969) noted that organophosphate insecticides trichlorfon and ronnel, reduced the fertility of housefly eggs. Exposure to carbamate or organophosphate insecticides caused gravid female German cockroaches to drop their oothecae prematurely, resulting in decrease hatch (Harmon and Ross 1987, '88). These observations by different authors on biological effects of insecticides belonging to different chemical groups offered a stimulus to further probe the biological effects of some new (modern) organophosphate and carbamate insecticides on hemipterous (Hemimetabola) and lepidopterous (Holometabola) insects which are also different in food habits.

Therefore, in the present investigation, the effects of sublethal concentrations of acephate, ethion, dichlorvos (organophosphates) and furadan, carbaryl, aminocarb (carbamates) were studied with particular reference to their effects on mortality, moulting, longevity, fecundity and fertility of *Dysdercus cingulatus* F. (Hemiptera: Pyrrhocoridae) and *Diacrisia obliqua* (Lepidoptera: Arctiidae). The red cotton bug, *D. cingulatus* is an important pest of cotton in Uttar Pradesh, Bihar, Madhya Pradesh, Bombay, Madras and Punjab (Sohi, 1964), it also feeds on vegetables, sorghum, ragi, oil seeds, small millets, sugar cane, peddy, guinea grass, jute, sunn hemp, beet root, potato and sweet potato (Mathur,1962), other malvaceous plants, wheat, maize, bajra and certain other agricultural and fibre crops and medicinal plants of economic value. Both the nymphs and adults feed gregariously on leaves and bolls of cotton plants. The yellow excreta of the bug stain the lint and spoil its quality. The Bihar hairy or

jute hairy caterpillar, *Diacrisia obliqua* Walker (Lepidoptera:Arctiidae) which is presently known as *Spilosoma obliqua* is a versatile, widely distributed polyphagous pest reported practically from all over India specially from Bihar, Madhya Pradesh, Uttar Pradesh and Punjab causing damage to a large number of cultivated (such as sesamum, mash, mung, linseed, mustard, some vegetables etc.) as well as non-cultivated plant species (Fletcher, 1922; Sevastopulo, 1940; Mathur 1962; Dutt, 1964; Pandey *et al.,* 1968; Kabir and Khan, 1969; Gargav and Katiyar, 1971; Viswanath and Gowda, 1975; Deshmukh *et al.,* 1976; Bhattacharya and Rathor, 1977). The host range of this insect pest is still increasing. Beside India, this pest has been reported from Myanmar, Bangladesh, Pakistan and Srilanka. It is a sporadic but serious pest which causes almost complete devastation of entire fields whenever it appears in an epidemic form. Several outbreaks of this insect have been reported during recent past (Anonymous,1969; Prasad and Chand, 1980a). Nowadays this has assumed the status of major pest in the priority list of pests which need attention to develop a safer management programme (Singh and Bhattacharya, 1994).

Further to correlate the sterility and infecundity by the present chemicals (organophosphates and carbamates), anatomical and histological observations were also made on gonads of the treated (affected) and untreated (control) adults.

It is further expected that the application of sublethal concentrations of the present insecticides on one hand may throw light on their comparative effectiveness in causing mortality, moulting disorder, reproductive inhibition and pathological effects on gonads and on the other hand the prospects of pollution by these selected insecticides as well as toxic hazards to non-target organisms may be reduced, yet the net results will be in the favour of agricultural economy.

II-REVIEW

In insect pest management, emphasis has mostly been given to the mortality of the pests caused by the chemicals rather than on the biology and the physio-toxicity of the insects that survive following application of the chemicals. The exposure of insects to sublethal doses of insecticides may result in the alteration in biology as well as in physiological processes. These effects may differ withregard to chemicals of different nature as well as from species to species. A fair amount of direct but frequently contradictory experimental evidences has been recorded showing the effects of sublethal doses of various insecticides on the biology of insects. There are reports which suggest that exposure to sublethal doses of insecticides reduce fecundity, fertility and longevity of the target insects (Moriarty, 1969; Haynes, 1988; Mackenzie and Winston, 1989; Hamilton and Schal, 1990; Abd-Elghafar and Appel, 1992; Khowaja *et al.*, 1993, '94). Georghiou (1965); Yokoyama and Pritchard (1984) recorded that sublethal doses had no effect on longevity and egg fertility. On the other hand, other investigators found that insects treated with sublethal doses produced more eggs, enhanced egg viability and lived longer than the untreated insects (Afifi and Knutson, 1956; Kuenen, 1958; Kuipers, 1962; Ball and Su, 1979; Farlow and Pitre, 1983; Abd-Elghafar and Appel, 1992; Khowaja *et al.*, 1993, '94). Encarnacion (1969) studied the normal biology of the red cotton bug *Dysdercus cingulatus* and recorded an average of 465 eggs per female.

In dictyoptera, the treatment of pyrethrins to adult females of German cockroach resulted in deposition of premature oothecae (Woodbury,1938; Parker and Campbell, 1940; Abd-Elghafar *et al.*, 1991). Cochran (1985) observed that the female German cockroaches failed to mate or produce oothecae when fed low concentration (< 6 ppm) of avermectin B_1. Exposure to carbamate or organophosphate insecticides caused gravid female German cockroaches to drop their oothecae prematurely, resulting in decreased hatch (Harmon and Ross, 1987, '88). Appel and Abd-Elghafar (1990) reported that sulfuramid increased oothecal drop, decreased hatch from oothecae that were dropped or retained, and increased the time to oothecal hatch in gravid female German cockroaches. Similar results were obtained when gravid females were treated with increasing doses of 10

different insecticides formulations (Abd-Elghafar *et al.*, 1991). Fecundity and longevity of 2-day old adult female German cockroaches were significantly reduced after the topical application of Lc-10, Lc-20 and Lc-60 of chlorpyrifos methyl (Hamilton and Schal, 1990). The topical application of the sublethal concentrations (LD_{20}, LD_{30}, LD_{40}, and LD_{50}) of cyfluthrin and hydramethylmin on German cockroach, *Blattella germanica* (L.) resulted in reduction in fecundity and fertility with increasing sublethal concentrations. The topical application of LD_{50} of cyfluthrin and LD_{30} of hydramethylmin resulted in 51 and 89% decrease in number of oothecae, respectively, whereas, the number of oothecae that hatched was decreased by 46 and 81% following the topical application of LD_{50} and LD_{20} of cyfluthrin and the hydramethylmin, respectively, as compared to the control (Abd-Elghafar and Appel, 1992).

In hemiptera, Osmani *et al.* (1984) observed that the topical application of 0.001 ml drop of 0.5 µg E.D.F. (ethyl 7,11-dichlorofarnesoate [ethyl 7,11- dichloro-3,7,11- trimethyl - 2 - dodenoate]) on adult *Dysdercus cingulatus* resulted in infertility in all 4 batches of eggs while treatment of adults with lowest dose (0.05 µg EDF/ml acetone) permitted hatching in the 3rd and 4th batches but not in the first two batches. Chatterjee *et al.* (1985) found ovicidal and sterilizing activity of some newly synthesized complex of iron and cobalt in eggs and early 5th instar nymphs of *Dysdercus koenigii* and most of the compounds reduced the egg hatch. In adult *D. cingulatus* the males have abundance of mature spermatozoa just after emergence, whereas, the females of the same age group have immature ova. Therefore, the newly emerged females exposed to any chemical might be more susceptible than the males of the same age group. Ansari and Khan (1973) further proved that the contact effect of (1.4 mg/sq.inch) triphenyltin acetate (TPTA) to adult females of *D. cingulatus* developed higher reduction in both fecundity and fertility. Hodjat (1971) observed that the topical application of 0.8- 6.0 µg dieldrin per 5th instar nymphs of *D. fasciatus* suppressed egg production, and 0.6-6.0 µg doses/individual reduced the fertility of the eggs. However, the topical application of lower doses (sublethal) of dieldrin (0.2 to 0.6 µg/nymph) enhanced the egg production. Similarly, Yokoyama

and Pritchard (1984) studied the comparative effect of sublethal doses of methidathion, carbaryl, methomyl, dicofol, propargite, glyphosate, DEF and sulfur as cotton leaf residues on *Geocoris pallens* Stal and recorded that the females exposed to DEF (defoliant) laid more eggs, whereas, the females which were exposed to glyphosate (herbicide) and methomyl laid more viable eggs. The sublethal concentrations (25-50 ppm of active substance, thiometon) of Intration-50 when applied on *Pyrrhocoris apterus* enhanced ovariole maturation during the activation of diapause individuals (Houck and Novak, 1978), whereas, the topical application of sublethal concentration (30 ppm) of monocrotophos per 5th instar nymphs of *D. cingulatus* resulted in 18 and 22% reduction in the average fecundity and fertility of the emerged females, respectively. However, the longevity of the survived nymphs, adult males and females enhanced significantly than the control (Khowaja *et al.*,1994).

In lepidoptera, Chattoraj and Bhise (1980) observed that the fecundity of *Spodoptera litura* females emerged from the treated larvae exposed to sublethal dose (3 μg) of dieldrin reduced significantly than control. In laboratory test, the exposure to sublethal concentrations (Lc-30, i.e. 0.0088% and Lc-50 i.e. 0.0182%)of parathion (ethyl parathion) to the larvae of *Spodoptera litura* resulted in reduction in oviposition and hatching rate of the adult females (Patil and Khanvilkar, 1977). On the contrary, Harnoto *et al.* (1984) presented an evidence from the laboratory studies that the exposure of larval stages of *S. litura* to sublethal doses (75 μg/g) of carbaryl stimulated the emerged females to lay more eggs than those females which developed from the larvae that were not exposed to this chemical, and recorded up to 47.6% increase in egg production. Abdel-Salam and Nasr (1968) concluded that larvae of the Egyptian cotton leafworm treated with trichlorfon, toxaphane or carbaryl had an increased developmental period, whereas, the deposition of eggs was decreased when the treatment was made with toxaphane and carbaryl only. Similarly, the topical application of sublethal doses of carbaryl (26 μg/larva) on *Spodoptera littorallis* (Boisduval) produced a detrimental effect on egg hatching, whereas, the same treatment induced an increase in preoviposition and oviposition period as well as longevity of the males and the female (Abo-Elghar *et al.*,1972). Livingston *et al.* (1978) observed that the exposure to 3075 ppm benomyl to

Trichoplusia ni resulted in almost total sterility of the males, while 5536 ppm of benomyl to *Pseudoplusia includens* resulted in 40% reduction in hatching when paired with treated males. Dabbor and Sayed (1982) observed that exposure to trichlorex of black cutworm *Agrotis ypsilon* resulted in significant increase in the larval duration. However, an increase in the fecundity but decrease in hatchability was recorded when the larvae were treated with carbaryl and linden, respectively. In search for effective compounds to control the pink bollworm, *Pectinophora gossypiella* (Saunders), Robertson (1948) reported that DDT was not only effective in killing the larvae and adults but also caused a reduction in the number of eggs produced by survived treated adults. Later, Williams *et al.* (1958) found a number of insecticides that would kill the adult of *P. gossypiella* and reduced the fecundity of the surviving insects. Further, DDT applied at field dosages was found to produce mortality ranging from 53 to 77% and reduced the number of eggs produced per moth from 81 to 94%. The topical application of 1 µl solution of DDT in acetone at 0.125 µg and 0.25 µg dose to the adult pink bollworm, *P. gossypiella* (Saunders) resulted in the production of fewer eggs and lived for fewer days than the untreated insects (Adkisson and Wellso, 1962). Essac *et al.* (1972) noticed that *Spodoptera littorallis* (Boisduval) adults, emerged from the survived larvae after the application of sublethal doses of carbaryl and methyl parathion, oviposited more eggs than the control females. On the other hand under similar conditions, larvae treated with endrin oviposited fewer eggs. The topical application of the higher selected sublethal concentrations (1250, 5000, and 10,000 ppm) of cythion (malathion) per 6th instar larvae of *Spodoptera litura* resulted in 18.2, 13.3 and 10.7% reduction in fecundity and 14.97 , 13.26, and 12.46% reduction in fertility, respectively. However, the same treatment enhanced the longevity of the larval as well as pupal stage (Khowaja *et al.*, 1993). Speyer (1924); Kalandaze (1927); Friederich and Stainer (1930) found that lepidopterous larvae poisoned with arsenicals developed into partial or complete sterile adults. When the moth *Plodia interpunctella* (Hubner) were treated with malathion, they laid less number of eggs which was dose dependent (Soderstrom and Lovitt, 1970). Ferguson, (1942) reported that copper arsenate reduced the fecundity of southern armyworm, *Prodenia eridania* (Gramer), but fertility was apparently unaffected.

In diptera, Styezynska *et al.* (1969) noted that organophosphate insecticides, trichlorfon and ronnel reduced the fertility of housefly eggs. Pree (1980) studied the toxicity of some insecticides to eggs and larvae of the apple maggot, *Rhagoletis pomonella* in laboratory and recorded that fenthion and azinophosmethyl were more ovicidal than phosalone, phosmet or dimethoate. The topical application of sublethal dose of (0.3 μg/fly) of Isolan® (1-Isopropyl-1-3-methyl-5-pyrazolyl dimethyl carbonate) to adult house flies, *Musca domestica* L. resulted in 35.8% reduction in total egg production, while doses of 0.6 μg (LD_{10}) and 1.0 μg (LD_{30}) reduced the egg production by 43.1 and 77.2%, respectively, (Georghiou, 1965). Ingestion of sublethal doses of arsenates by 4 species of adult diptera *Rhagoletis pomonella* (Walsh), *Drosophila melanogaster* Meigen, *D. hydei* Sturtevant and *Musca domestica* was found to suppress egg production through a suppressing effect on ovarian development (Pickett and Patterson, 1963). The ovicidal action of some insecticides was studied by Siddappaji *et al.* (1979) who recorded that methamidophos, quinolphos and trichlorphon showed excellent ovicidal action (100% inhibition at 0.025% concentration). Brydy *et al.* (1970) observed that the female houseflies, *M. domestica* were more susceptible to TPTA than the male houseflies. The experiments of Kenaga (1965) on the houseflies suggested that the sterilizing effect of organotin compounds was more marked on developing gonads rather than on matured gonads. Kissam and Hays, (1966) also found that triphenyltin acetate and triphenyltin chloride were effective reproductive inhibitors but their toxicity to houseflies was high at very low dosages. Hunter *et al.* (1958, '59) recorded 32-34% biotic reduction in the fecundity, fertility, longevity and survival of the progeny in resistant strains of houseflies *M. domestica* L., when treated with sublethal doses of DDT or diazinon. The oviposition of the resistant strain of houseflies was almost ceased when the adults were exposed to sublethal concentrations of 4,4'-dichloralpha (pentafluoroethyl) benzahydrol (Ascher, 1957). On the contrary, Knutson (1955) found that fruit flies, *D. melanogaster* Meigen, surviving the effect of sublethal dose of dieldrin produced 7.6% more eggs than the control, whereas, the increase in egg production was explained as a result of increased fly longevity following exposure to dieldrin. Similarly, Ouye and Knutson (1957) demonstrated that 2 ppm malathion incorporated into larval media of the

housefly produced 40-60% kill. However, the survivors had a 12% increase in their net reproduction rate. DDT treated housefly population showed a modified reproductive biology disadvantageous to the flies (Beard, 1960).

In hymenopterous insects, according to Grosch (1963), the ingestion of sublethal doses of sodium arsenite by the braconid wasp *Bracon hebetor* Say, which at eclosion had mature ovaries, also resulted in reduction in egg laying, and he attributed this reduction to the occurrence of a general somatic debility rather than to specific cytological effect upon the germ line. The exposure of various sublethal doses of diazinon, either once or repeatedly to the worker bee, *Apis melifera* reduced their longevity (Mackenzie and Winston, 1989).

In coleopterous insects, Ridgway *et al.* (1965) observed that the feeding of artificial diet containing American Cyanamid CL-47031 (Cyclic ethylene (diethoxyphosphinyl) dithioimidocarbonate), CL-47470 (Cyclic propylene (dimethoxyphosphinyl) dithioimidocarbonate) and phorate at 2, 1 and 2 ppm, respectively, to newly emerged boll weevils *Anthonomus grandis* Boheman, greatly reduced oviposition than the control. Bariola and Lindquist (1970) observed that the continuous exposure of sublethal doses of disulfoton, dicrotophos, monocrotophos and aldicarb (0.25, 0.9, 0.8 and 0.025 mg/dish, respectively) to adult boll weevils *A. grandis* Boheman through filter paper impregnated with insecticides resulted in 62, 40, 23 and 42% reduction in egg oviposition, respectively, by the surviving females during 10 to 14 days period. A significant reduction in oviposition of the females of the confused flour beetle, *Tribolium confusum* Jacqueline DuVal, was observed following the exposure of high concentrations of DDT, though the survivors of lower concentrations showed only a slight reduction in oviposition (Loschiavo, 1955). The fecundity and longevity of the red flour beetle *Tribolium castaneum* that survived LD-50 dose of malathion or dichlorvos reduced significantly than untreated insects (Zettler and Luato, 1974). El-Nahal and El-Halfway (1973) showed that the sublethal doses of CS_2 decreased the oviposition period and the number of eggs laid per females both the survivors a well a their progeny. However, low sublethal doses stimulated fecundity of the survivors of all 3 species. Egg deposition was inhibited, hatchability was decreased and the longevity became considerably less as

compared to the control. Parker *et el.* (1977) concluded that sublethal doses of malathion had greatest effect on fecundity at the higher selected doses used against *Menochilus sexmaculatus.* Reduction in longevity and viability of eggs with increased toxicant concentration was also observed. Van Mallaert *et al.* (1984) evaluated the insecticidal activity of 5-methoxy-6-(1-[methoxyphenyl]-1,3-benzodioxole against the colorado potato beetle *Leptinotarsa decemlineata* and recorded reduction of egg hatch at concentration as low as 10 ppm. Adult of *Callosobruchus chinensis* L., which survived a single treatment of endrin produced fewer eggs than the control. However, when untreated females were mated with treated males, there was an increase in egg production (Kiyoku and Tamaki, 1959). On the contrary, Ball and Su (1979) demonstrated that the females of *Diabrotica virgifera* treated with sublethal doses of carbofuran and carbaryl, oviposited significantly more and lived significantly longer than the control females. Katiyar and Lemonde, (1972) observed that the feeding of 0.01% Landrin, 0.003% Aldicarb, 0.004% Akton and 0.021% SD-7438 to the larvae of *T. confusum* Jacqueline duVal resulted in 76.6, 30.9, 73.4 and 75.5% reduction in the average egg production of the survived females and fertility of the eggs decreased by 97.4, 26.2, 69.6 and 75.0%, respectively, as compared to the control. On the contrary, the feeding of 0.006% Gardona, 0.004% monocrotophos and 0.034% UG-20047 to the larvae of *T.confusum* showed 21.6, 25.7 and 28.3% increase in the average egg production, whereas, the enhancement in fertility was more significant (71.08, 74.83 and 72.4%, respectively) as compared to the control. Kuipers (1962) found that sublethal doses of DDT or methyl parathion had a stimulatory effect on egg production of the colorado potato beetle, *Leptinotarsa decemlineata* (Say.). In contrast, Johansson (1950) observed that feeding of the sublethal doses of sodium fluoride, administered with flour, to confused flour beetle *T. confusum* Jacqueline duVal, resulted in reduction in fecundity.

Inhibition in fecundity and fertility of insects which are exposed to insecticides can be expected to go through some changes in histological and physiological processes in the gonads. But histopathological effects of conventionally used insecticides on insect gonads have generally received very little attention hence our knowledge in this regard is very scanty, which was conformed by Ahi (1988) and

Mulmule *et al.* (1988). Further, most of the studies regarding the histopathological effects of pesticides on insect gonads are related to chemosterilants. In this regard available information has been reviewed to evaluate comparative effect of chemosterilants on the gonads of insects with that of the present observations on the gonads of *Dysdercus cingulatus* and *Diacrisia obliqua* by the application of the selected organophosphates (acephate, ethion, and dichlorvos) and carbamates (furadan, carbaryl and aminocarb) tested during the study.

According to Ahi (1988), the injection of 0.001% hexachloro-cyclohexane (a chlorinated hydrocarbon) on alternate days to the male grasshopper *Poecilocerus pictus* (Orthoptera) resulted in loosening of the germ cells, pycnosis of the spermatogonia and spermatocytes, hypertrophy of spermatids and dissociated spermatozoa. When *Mylabris pustulata* was treated with SAN-322 and DDVP, the ovaries showed vacuolation within the yolk, distorted shape of oocytes, picnosis or condensation of oocyte nucleus and necrosis of follicular epithelium (Mulmule *et al.*, 1988).

According to Borkovec (1962), partial or full sterility can be achieved by treating the organisms with chemicals. The observations on the use of chemicals to induce sterility in insects have comprehensively been reviewed by Borkovec (1966) and LaBrecque and Smith (1968). Further, a number of general as well as specific informations on the use of various chemicals leading to sterilization of insects have been reported by Ascher (1970); Borkovec (1969); Campion (1972); Zakharova (1969); Stuben (1969); Mourikis and Fytizas (1970); Landa and Matolin (1971); Grosch (1971); Matolin *et al.* (1978); Tanya *et al.* (1979); Ahmad (1980); Shehata (1982); Shankar and Tripathi (1986); Aji *et al.* (1986); Moursy and Eesa (1988).

Initially, investigators concentrated to observe the induction of lethal mutations by alkylating agents (chemosterilants) including tretamine and alkane sulphonates during spermatogenesis and oogenesis in *Drosophila melanogaster* (Fahmy and Fahmy, 1954, '64; Roehrbom, 1962). Later, workers concentrated on observations leading to sterility produced by exposing the insects to certain chemicals. Out of the 8 S-triazines, only one (N,N-diethylene melamine

hydrochloride) could induce 90% sterility in adult Japanese beetle, *Popillia japonica* by dipping technique (Ladd, 1970). Topical application of tretamine either on pupae or adults of *Epilachna vigintioclomaculata* induced complete sterility in both sexes (Bulgginskaya *et al.*,1972). Besides the alkylating and non-alkylating compounds some organic sulphur compounds such as thiourea and sulphanilic acid also induced sexual sterility in *D. cingulatus* (Ahmad, 1990).

In lepidoptera, (Heliothis virescens), tretamine was most effective chemosterilant on both sexes when applied topically, or by feeding (Wolfenbarger *et al.*, 1974). Topical application of 15 µg of tepa/adult induced a high degree of sterility in the male and the female codling moth, *Carpocapsa somonella* (L.).

In diptera, the contact effect of 2-chlorethyl ethanesulphonate and 2-chlorethyl methanesulphonate to *Musca domestica* was quite effective in inducing hundred percent sterility in the males and complete infecundity in the females (LaBrecque and Meifert, 1970). However, 1,3-propane diol dimethanesulphonate caused fifty percent dominant lethal mutations in *Culex pipiens* (Amirkhanian, 1971). On *Anthonomus grandis*, busulfan established 97 percent permanency in sterility in males without affecting pheromones and drastically reduced fecundity in the females (Klassen and Earle, 1970). On the other hand, McHaffey *et al.* (1972) recorded sterility only in females of *A. grandis* by diethyleneglycol dimethane sulphonate and 1,3-propandiol dimethane sulphonate. Graves *et al.* (1965) was the first to reported the insecticidal effect of certain tin compounds such as triphenyltin acetate, trimethyltin hydroxide, tributyltin oxide and diethyl-n-octyltin acetate on *Heliothis* species. Both Brestan (a wettable powder containing 60 percent triphenyltin acetate) and Duter (a wettable powder containing 50 percent triphenyltin hydroxide) proved as promising insecticides for the control of *Mammestra brassicae* (Camprag *et al.*, 1969). Tributyltin oxide also had insecticidal value, and was as good as DDT and Sevin, against the red bollworm *D. castanca* when applied either topically or by injection (Campion and Outram, 1968).

Some workers also evaluated the sterilizing activity of organometallic compounds against lepidopterous pests. Both triphenyltin acetate and hydroxide

reduced the fecundity as well as fertility of *Spodoptera littorallis* (Findlay, 1970b). But feeding of these compounds below toxic dosages throughout their adult stage induced significantly higher sterility (Findlay, 1970b; Mitri and Kamel, 1972). Both topical and oral application of Du-Ter to larvae of *Agrotis ypsilon* significantly sterilized the resulting adults (Shaaban *et al.*,1975).

The biological effects of organometallic compounds were comparatively less studied on coleopterous pests. Kenaga (1965) reported that triphenyltin compounds were effective in suppressing or controlling the reproduction in *Tribolium confusum* and *Blattella germanica.*

Most of the studies regarding the effects of different chemicals on the gonads were confined to the ovaries of different insect species. These observations were reviewed by Hays (1964), Borkovec (1966); LaBrecque and Smith (1968); Knipling *et al.* (1968); Landa and Matolin (1971); Grosch (1971) and Campion (1972). Whereas, LaChance and Crystal (1963); Morgan (1967); Morgan and LaBrecque (1962, '64); Rai (1964) and many others have studied the effects of certain chemicals on reproductive organs of houseflies, mosquitoes and other insects and recorded inhibition in ovarian development. Histological examination of reproductive tissues has revealed regeneration of oocytes and general necrosis following the application of these chemicals. But, these investigators were mostly confined to dipterous insects which have polytrophic type of ovaries. Such affected ovaries generally suffered with retardation or complete cessation of growth and maturation as in *M. domestica* (Sakurai, 1974); *D. melanogaster* (Merle, 1973; Pare *et al.*, 1974); *Cochliomyia homimivorax* (Crystal, 1970 a,b), *Culex pipiens* (Grover *et al.*, 1972). In *M. domestica* tepa, thiotepa and apholate caused condensation and pycnosis of nuclei, vacuolization of cytoplasm and general atrophy of follicular epithelium of the ovaries (Morgan and LaBrecque,1964; Landa and Rezabova, 1965; Combiesco *et al.*,1967). Similar effects were produced by hempa, p',p'-bis(1-aziridinyl)-N-methyl-phosphinic amide and p,p-bis(1-aziridimyl)-N-(3-methoxy propyl) phosphinothionic amide (Morgan, 1967; Wilson and Hays, 1969). However, Kissam *et al.* (1967) reported little change in the ovarian histology of *M. domestica*, following application of tretamine and methyl methane sulphonate.

Among coleoptera, the topical application of metepa and hempa on *Trogoderma granarium* (Metwally, 1972) and apholate on *Hypera postica* (Hsieh and Pienkowski, 1973) mostly damaged the upper zone of the female germaria where trophocytes proliferates. Similar changes were found in *Tribolium confusum* and *T. molitor* by reserpine (Masner *et al.*, 1970) and in *Acanthoscelides obtectus* by tepa (Ondracek and Matolin, 1971). In the ovarioles of thiourea fed, *Epilachna dodecastigma*, the size of the ovarioles reduced significantly and the follicle cells remained columnar without intercellular spaces, resulting in the inhibition of transport of vitellogenin (Shanker and Tripathi, 1986). The topical application of metepa to adult colorado beetle *Leptinotarsa decemlineata* interfered with the formation of oocytes, damaging their structure and caused proliferation of follicular epithelium (Matolin *et al.*, 1978).

In certain lepidoptera such as *Cadra cautella* (Gangrade and Pant, 1970), *Agrotis segetum* (Ivanova, 1970); *Trichoplusia ni* (Henneberry *et al.*, 1972); *Heliothis zea* and *H. virescens* (Guerra, 1970), there was inhibition of ovarian growth following the treatment with certain alkylating and non-alkylating agents, whereas, in *Laspeyresia pomonella* (Kozhanova *et al.*, 1973) there was partial resorption of oocytes. In *C. cautella* (Gangrade and Pant,1970) the ovarioles were damaged anteriorly at the time of rapid proliferation and differentiation of cells. However, in *L. pomonella* injection of thiotepa in the larvae did not affect the follicular cells of the ovarioles (Kozhanova *et al.*, 1973). Topical application of thiotepa and hempa on diamond-back moth, *Plutella xylostella* L. resulted in 100% sterility with the inhibition of oogenesis and vitellogenesis (Lau and Sudderuddin, 1979). The pupal dip of jute stem weevil *Apion corchori* (Marsh) in 0.5% apholate for 90 seconds resulted in inhibition of gonadal development of both sexes (Ghatak, 1992).

In hymenoptera, histopathological damage in the ovaries by different chemicals was generally recorded on *Habrobracon* or *Bracon*. There was reduction in the size of the ovarioles accompanied with signs of chromatin clumping and degeneration following the application of methotrexate on *B. hebetor* (Grosch, 1963) and that of apholate and 6-mercaptopurine (Cassidy and Grosch, 1973). In *B.*

hebetor after the injection or residual treatment with 1-naphthyl (Hydroxymethyl) carbamate, 1,5-dihydroxynaphthalene or 1,3,5-trichlorobenzene, the mitotic apparatus of the germarium was damaged, whereas, egg production was reduced slightly (Grosch and Hoffman, 1973).

In orthopterous insects, the histopathological effects of chemosterilants on the ovaries were studied only in German cockroach (*Blattela germanica*), whereas, reduction in the number of basal oocytes as well as gradual disintegration of the ovarioles occurred by tepa and apholate (Burden and Smittle, 1963; Smittle *et al.*, 1966; Vingiello and Ross, 1967).

According to Bhargava *et al.* (1977), the exposure of *Periplaneta americana* L. to hempa resulted in damage of mature oocytes more than the immature ones by causing vacuoles formation in the cytoplasm and breaking of the interfollicular tissue. This action of hempa resembles that of apholate, metepa and thiotepa as described by Tandon and Bhargava (1977). The effective dose of hempa, thiotepa and Bis(Dimethylamino)Dithiazolium chloride (Sexena and Bhatnagar, 1980) caused severe pathological damages to the panoistic ovary of *P.americana* (L.) leading to degeneration and dissolution of ovariole cytoplasm, pycnosis and fragmentation of chromatin material in oogonia and follicular cells.

The histopathological effects of chemicals on the ovary of hemipterous insects have been studied in variety of species. Rao *et al.* (1986) observed that the topical application of 20 μg/μl dose of 2-[1-(2-methyl-5-nitroimidazole]ethyl phenylacetate (an analogue of fenvalerate) on freshly eclosed fifth instar nymphs of *Dysdercus similis* resulted in the reduction of oocytes, inhibition of vitellogenesis and resorption of the basal oocytes of the affected ovaries. In red cotton bug, *Dysdercus cingulatus* (Sukumar and Naidu, 1973) and in *Oncopeltus fasciatus*, (Economopoulos, 1971; Economopoulos and Gordon, 1971b) incomplete or complete inhibition of ovarian growth occurred by tepa and metepa. Injection of 12.5 μg metepa or 7.5 μg apholate to the newly emerged females *D. cingulatus* resulted in inhibition of oocyte development, disintegration of germarium and follicular epithelium as well as reduction in size of the oocytes (Jalaja and Prabhu, 1976).

The cytological effects of tepa on the reproductive organs of *D. cingulatus* showed continuous degeneration of the oocytes and follicular cells in the ovaries and spermatogonia in the testes of the adults (Ahmad, 1980). In *Pyrrhocoris apterus*, compound egg chambers formed in the ovarioles by antimetabolite treatment (Masner and Landa, 1971). Ameresekere *et al.* (!971) reported nuclear disintegration and cellular atrophy in beetleaf hoppers, *Circulefer tenellus* after application of N,N'-hexamethylenebis (1-aziridine carboxamide).

In contrast to ovary, the effect of alkylating agents on the testes were generally less marked. In *M.domestica* by feeding of tretamine and methylmethanesulphonate, Kissam *et al.* (1967) failed to detect any histological damage. On the other hand, feeding of thiotepa caused marked reduction in spermatogenesis, although, the structure of the testes as a whole remained intact (Cline, 1968). However, reduction in spermatocytes occurred by injecting 1,3-propanediol dimethanesulphonate, and some aziridines and hempa to houseflies (LaChance *et al*, 1970). In *D. oleae* (Haniotakis and Galachtiou, 1973) metepa caused sperm depletion, whereas, reserpine had no adverse effect on spermatogenesis (Fytizae, 1974). Grover *et al.* (1972) recorded reduction in the size of the testes by treating *Culex pipiens fatigans* with metepa and hempa along with slowed spermatogenesis. Aji *et al.* (1986) observed morphologically abnormal spermatozoa in the seminal vesicles of *Aedes togoi* following the application of metepa and hempa. In *H. postica* (Hsieh and Pienkowski, 1973) and *A. corchori* (Dutt and Mukherjee, 1970) testes size was also reduced following apholate treatment. On the other hand Masner *et al.* (1970) did not notice any anatomical change in the testes of *T.confusum* when treated with reserpine, although complete sterility developed in these males. Shehata (1982) observed marked reduction in the size of the male gonads after one week of treatment with metepa to the newly emerged adults of *Ceratitis capitata*.

In lepidoptera, there was no histological damage in the testes and accessory glands of *C. cautella* following the treatment of adults with apholate (Gangrade and Pant, 1970). Similarly, tepa and metepa could not cause any pathological changes in the testes of *Trichoplusia ni*, although volume of the testes of treated males

decreased with increasing concentrations (Henneberry *et al.*, 1972). In F_1 generation of eupyrine spermatozoa of *Bombyx mori* were found unbundled, otherwise testes were like those of normal (Sugai and Suzuki, 1971a), but the young spermatozoa were found to be most sensitive to apholate (Sugai and Suzuki, 1971b). When the males of *B.mori* were injected with aminopterin at prepupal stage, the testes of the adult were normal and the vasdeferens contained normal spermatozoa, but the number of spermatozoa in the ampulla ductus deferentis was reduced (Sugai and Ashoush, 1970).

In homoptera (*C. tenellus*), the treatment by N-N'-hexamethyl-enebis(1-aziridinecarboxamide) caused cell necrosis and sperm depletion (Ameresekere *et al.* 1971), whereas, in heteroptera (*O. fasciatus*), the treatment of tretamine, tepa and metepa did not have any apparent effect on the testes, except reduction in spermatogenesis and a little sperm inactivation (Economopoulos and Gordon, 1971).

In orthoptera, the injection of 0.1% sevin (1-naphthyl-n-methyl carbamate) showed clustering and spiralization in parts of spermatozoa in the testes of 48 hr. old dissected *Poecilocerus pictus* (Reddy *et al.*, 1974).

III- MATERIALS AND METHODS

i. Breeding and maintenance of stock culture of *Dysdercus cingulatus*

Adults of *Dysdercus cingulatus* were collected from the cotton crop field during the Kharif period and were kept in glass rearing jars measuring 20x15 cm. containing a damp peat about 5 cm thick at the bottom. The top of these jars was covered with a piece of muslin cloth tightly fixed by means of a rubber band. These rearing jars were kept at 29±1°C and 70-80% R.H. in a B.O.D. incubator (Khowaja *et. al.*, 1994). These insects were fed on water soaked healthy cotton seeds which were changed daily. After egg laying, the adult insects were transferred to fresh rearing jars. Over-crowding was avoided. On hatching, the nymphs were daily provided with soaked healthy cotton seeds.

ii. Breeding and maintenance of stock culture of *Diacrisia obliqua*

Adult moths of *Diacrisia obliqua* presently known as *Spilosoma obliqua* were collected around the lamp posts in the months of September and October. These adults were maintained in glass rearing jars measuring 20x15 cms. Each rearing jar was covered with a piece of muslin cloth which was tightly fixed by means of a rubber band and maintained at 29±1°C temperature and 70-80% R.H. in a B.O.D. incubator cabinet (Khan *et al.*, 1990) Adult moths were fed on saturated glucose solution (Hashmat and Khan, 1970). For this purpose a piece of sterilized cotton wool was wrapped around a glass slide and it was soaked with fresh glucose solution. Such slides were obliquely placed against the jar wall. Freshly prepared cotton wool slides soaked with fresh sucrose solution were daily replaced. The females laid eggs on folded paper strips 2"x20" kept in the jars and then the adults were transferred to fresh jars. After hatching, the young larvae were fed on fresh tender castor (*Ricinus communis*) leaves. The jars having larval forms were cleaned and fresh leaves were provided daily. These larvae pupated at the surface of the jars or at the under surface of the leaves. The emergence of adults took place after a week following pupation.

Then the newly emerged adults were transferred in pairs to separate rearing jars for further generations.

iii. Sampling of experimental insects

In the present research programme, two advanced stages (4th and 5th instar nymphs) of *D. cingulatus* and 5th and 6th instar larvae of *Diacrisia obliqua* were used. For this purpose, with respect to *D. cingulatus,* sample of freshly moulted 3rd instar nymphs between 9.00 am. and 12.00 noon each day were isolated and maintained age wise. Similarly freshly moulted 4th instar larvae of *D. obliqua* were also isolated during 9.00 am and 12.00 noon daily. Subsequently, 4th and 5th instar nymphs of *D. cingulatus* and 5th and 6th instar larvae of *D. obliqua* were treated for observation as described below. The moulting of nymphs or the larvae were visually ascertained by the larval head capsule. At that time such nymphs or larvae were considered to be of zero age. After one day (24 hr.) following zero age i.e. w.e.f. 12.00 noon nymphs or larvae were treated with the selected insecticides.

iv. Dilution and application of chemicals

In the present investigation three organophosphate compounds of different chemical nature namely Acephate (O, S-dimethyl acetyl phosphoramidothioate); Ethion (S, S-methylene bis (O, O-diethyl phosphoro dithioate); Dichlorvos (2, 2-dichloroethenyl dimethyl phosphate); and another three carbamate compounds namely Furadan (2, 3-dihydro-2,2-dimiethyl-7-benzofuranyl methyl carbamate); Aminocarb (4-(dimethylamino)-3-(methylphenylmethyl carbamate), and Carbaryl (1-nephthalenyl methyl carbamate) were used for topical application on the aforesaid stages of *D. cingulatus* and *D. obliqua.* All these chemicals were obtained with courtesy of Rallis India, as gift samples. The effect of these chemicals was observed on mortality, moulting, longevity, fecundity, fertility and reproductive system of *D. cingulatus* and *D. obliqua* by using five sublethal concentrations of each insecticide on the basis of Lc-50 value respectively. To make a stock solution first, 1 gm of each insecticide was separately dissolved in 100 ml acetone (Analar, B.D.H.) to get a 1%

w/v solution of each chemical. For both the nymphal stages of *Dysdercus cingulatus*, the stock solution of organophosphates were further diluted as:

Acephate: 0.002%, 0.001%, 0.0008%, 0.0006%, 0.0004%
Ethion: 0.006%, 0.004%, 0.002%, 0.001%, 0.0008%
Dichlorvos: 0.01%, 0.008%, 0.006%, 0.004% 0.002%

Likewise, the stock solution of carbamates were also further diluted as:

Furadan: 0.001%, 0.0008%, 0.0006%, 0.0004%, 0.0002%,
Aminocarb: 0.004%, 0.002%, 0.001%, 0.0008%, 0.0006%
Carbaryl: 0.0025%, 0.002% 0.0015% 0.001%, 0.0005%

Similarly,for *Diacrisia obliqua*, the stock solution of organophosphates were further diluted as:

Acephate: 0.1%, 0.08%, 0.06%, 0.04%, 0.02%,
Ethion: 0.6%, 0.4%, 0.2%, 0.1%, 0.08%
Dichlorvos: 0.4%, 0.2%, 0.1%, 0.08%, 0.06%

Likewise, 1% stock solution of carbamate insecticides were further diluted as:

Furadan: 0.08%, 0.06%, 0.04%, 0.02%, 0.01%
Aminocarb: 0.25%, 0.2%, 0.15%, 0.1%, 0.08%
Carbaryl: 0.15%, 0.1% 0.08%, 0.06%, 0.04% for both the larval stages (5th and 6th instar).

From each concentration of diluted insecticides only 1 µl was applied topically on the metathoracic pleuron of individual 4th and 5th instar nymphs of *D. cingulatus*. Whereas 2 µl solution of each diluted concentration was applied on the individual 5th and 6th instar larvae of *D. obliqua* by 26 gauge needle attached to a tuberculin syringe fitted into a manually operated microapplicator. At the time of topical application of insecticides, the age of experimental insects was one day. For each concentration 100 nymphs or larvae in four replicates, each consisting of 25 insects, were used. Two controls consisting of same number of nymphs or larvae of same age were also run parallel to each series of experiment. One control group was treated with acetone (Solvent) only and served as control-I, while the other had untreated

nymphs or larvae of the same age and stock and served as control-II. The control groups were maintained at the same controlled conditions. When females subsequently emerged from the treated nymphs (*D. cingulatus*) or the larvae (*D. obliqua*), these were paired with the healthy males of similar age that emerged from their respective sets. Two controls were also run parallel to each series of experiment, control I had females emerged from only acetone solution treated nymphs, whereas control II contained females emerged from untreated nymphs or larvae. The data on mortality, moulting, longevity, fecundity and fertility were recorded on both treated and controlled insects.

V. Interpretation of data

The data on longevity, moulting, mortality, fecundity and fertility of *D. cingulatus* and *D. obliqua* affected by different concentrations of various insecticides were recorded for each replicate and mean value of four such replicates of each treatment was calculated. The determination of any change was not only ascertained arithmetically but appreciated by statistical analysis also. The standard deviation (S.D.) was calculated by the following formula:

$$S.D. = \sqrt{\frac{\sum D^2}{n-1}}$$

Where, S.D.= Standard deviation,
D = sum of square of the difference of mean value,
n = number of observations

On the basis of standard deviation(S.D.) standard error (S.E.) was calculated by the following formula:

$$S.E = \frac{S.D}{\sqrt{n}}$$

where, S.E. = standard error,
S.D.= standard deviation,
n = number of observations.

It was also necessary to appreciate the difference between mean values of different sets of samples. Arithmetically it was uncertain, therefore, we tested the

mean values statistically. For this purpose, the statistical technique of variation significance (t,test) was applied (Bailey, 1959) by using the formula.

$$t = \sqrt{\frac{m_1 - m_2}{\frac{S.D_1}{n_1} + \frac{S.D_2}{n_2}}}$$

where, t = significant value,

m_1 = Mean value of first set of observations

m_2 = Mean value of second set of observations

$S.D_1$. = Standard deviation of first set of observations

$S.D_2$ = Standard deviation of second set of observations

n_1 = Number of observations of first set

n_2 = Number of observations of second set

The calculated 't' was compared with the tabulated 't' (Bailey,1959) at 5% level. If the calculated value remained higher than the tabulated 't' value, the data are significant, otherwise insignificant.

Further, to measure the intensity of association between fecundity/fertility and concentrations of insecticides, a regression line was fitted to the data, followed by correlation analysis (Sockel and Rohlf,1981) using the formula:

$$Y = A + Bx$$

vi. Anatomical preparations

Active and healthy females which emerged from the survived treated and untreated nymphs were paired with their corresponding males. From such stock, 10 females and 10 males were dissected out simultaneously, at the intervals of 1, 5, 10 and 20 days following emergence, to study the changes both in anatomical as well as histological structure of the reproductive system. Similarly, the 10 pairs of *D. obliqua* were also dissected out at the same time on 3rd day following the emergence. For this purpose normal and affected adults were dissected in physiological saline containing 0.9 gm NaCl, 0.042 gm KCL, 0.048 gm $CaCl_2$, 0.002 gm $NaHCO_3$ in 99.0 ml distilled water and 1.9 ml acetic acid. Then, the dissected testes and ovaries were fixed in

Duboseq-Brasil fixative for one hour and washed with 90% ethanol repeatedly for several times over a period of 24 hr. (Pantin, 1959). Subsequently the material was brought to 70% ethanol to stain in borax carmine. Finally the stained tissue was dehydrated, cleared in methyl benzoate and benzene and mounted in Canada balsam.

vii. Histological preparations

For histological observations of the testes and ovaries of adults of different age groups, the respective gonads were removed in the physiological saline and fixed in Duboseq-Brasil for one hour because it gave excellent fixation as compared with Carnoy, Zenker, Smith's Formal Bichromate and Aqueous Bion. The tissues were washed in 90% ethanol, dehydrated, cleared in methyl benzoate and benzene and embedded in the paraffin wax (56-58°C melting point, Merck). Serial sections both cross and longitudinal of 5 to 8 micron thickness were cut on rotary microtome. These sections were stained with Heiden Hain's Iron Haematoxylin, Hansen's Iron Trioxy haematin and Mallory's triple stain but most promising results were available with Heiden Hains Iron Haematoxylin and Eosin. The slides containing paraffin sections were immersed in pure xylene to remove the paraffin by two changes of 15 and 5minutes respectively. The slides were later rehydrated to lower grades of alcohol (Absolute, 90, 70, 50, 30% and distilled water), for 5-10 minutes in each. The slides were immersed in haemotoxylin (delafied) for 3-5 minutes. After washing in distilled water the slides were dehydrated and passed through upgrade of alcohol up to 90%, 5-10 minutes in each. Following the partial dehydration up to 90% alcohol the slide were immersed for 10 minutes in 1% eosin dissolved in 90% alcohol. For the complete dehydration the slides were than passed through 2 changes of 5 minutes each in absolute alcohol. The cleaning of the slides was done by immersing in xylene for 15 minutes followed by DPX mounting. For absolute drying the slides were kept in incubator at 60 °c over night. The staining was achieved by YSI-106 Yorco automatic staining machine having 12 stations using Culling (1974) method. Details of normal anatomical and histological structures were reproduced by camera Lucida drawings. The important anatomical or histological changes were represented by photographs. All photomicrography was carried out by using Getner trinocular research microscope

mostly with blue filter fitted with camera. The subject was recorded by Practica (SLR) camera loaded with photosensitive emulsion film of Forte Pan 163 ASA 35 mm which is medium speed, medium contrast and ultra super fine film.

IV-RESULTS AND OBSERVATIONS

1.1. Effects of Topical Application of Sublethal Concentrations of Acephate on 4th Instar Nymphs of *Dysdercus cingulatus Fabr.*

1.1.1. Mortality, Moulting and Longevity

In the first set consisting of 100 nymphs of 4th instar which were topically treated with 1 µl of acetone only, the total nymphal mortality was 3% up to adult emergence, which was almost similar to that of untreated nymphs (control-II). The nymphs which survived after the treatment were quite active, healthy and moulted to adults successfully (Plate-I, Fig. A). Since there was no appreciable difference between the two controls, therefore, in the following text reference has been given to control-I only. In the second set, the topical application of the lowest concentration of acephate (0.0004%) on 100 4th instar nymphs did not cause any significant mortality either within the same instar or later up to adult emergence. The longevity of all the surviving treated nymphs was unchanged and they were very active like those of control-I. The total nymphal mortality up to adult emergence following the application of 0.0004% acephate was 4% more as compared to control-I (Table-1). In the third set, topical application of 0.0006% acephate resulted in 10% mortality within the same instar, whereas, 2 nymphs died during the 5th instar and one died due to incomplete nymphal-adult moulting. The total loss up to adult emergence was 10% more than the control. The longevity of the survived nymphs as well as adults were same as that of control, and they were active and competitive like the members of control group. In the fourth set of 100 nymphs treated with 0.0008% concentration of acephate, the mortality was 19 during the same instar and 5 at the next nymphal moulting. The survived nymphs were active like those of control. However, out of the adults which emerged from the survived nymphs, 4.9% had malformed wings. The total loss of life up to adult emergence was 25% which was 22% more than that of the control-I (Table1). In the fifth set of 100 nymphs following the topical application of 0.001% acephate to each nymphs, 31 nymphs died during

the same instar, whereas, 4 nymphs could not cast off their exuviae and died during the process of moulting. The mortality during the 5th instar and then at nymphal-adult ecdysis was 3 each. The emergence of adults was dropped by 3.8% as compared to the control. There was no significant change either in morphological appearance or the longevity during both the instars. But 7.2% adults which emerged from the survived treated nymphs showed malformation in their wings. In the sixth set of the experiment when 100 nymphs (4th instar) were treated with 0.002% acephate, 43 nymphs died during the same instar, whereas, 7 nymphs succumbed at next instar moulting (Plate-I, Fig. B). Further, 5 nymphs died during the 5th instar and 1 could not cast off the exuviae and died during the process of nymphal-adult ecdysis (Plate-I, Fig. B). The total nymphal mortality upto adult emergence was 56%, which was 53% more than the control (Table-1). Among the adults which emerged from the survived treated nymphs, 11.6% had malformed wings (Plate-I, Fig. F). The mean longevity of 4^{th} and 5^{th} instar nymphs was prolonged by 20 and 18%, respectively, as compared to the control. Whereas the mean longevity of adult males and females which emerged from the treated nymphs was increased by 24 and 16%, respectively, than the control (Table-25).

1.1.2. Fecundity and Fertility

The adults which emerged from the survived treated nymphs had no effect on their behaviour and were as competitive as those of controls. The newly emerged affected males were paired with females of same age of the same set to observe fecundity and fertility.

The average egg production of the females that emerged from survived treated 4th instar nymphs decreased linearly with increasing sublethal concentrations of acephate ($Y= 421.86 - 48362.07 X$, $r= - 0.9647$, $P<0.001$, Fig.1), showing a negative correlation coefficient. After the application of the lower concentrations (0.0004 and 0.0006%) of acephate, the average fecundity of the females reduced insignificantly by 3.29 ($t=1.6346$, $P>0.05$) and 8.45% ($t=2.5678$, $P<0.05$), respectively, as compared to the control (Table-1). Whereas on application of the higher sublethal concentrations, i.e. 0.0008, 0.001 and 0.002% acephate on

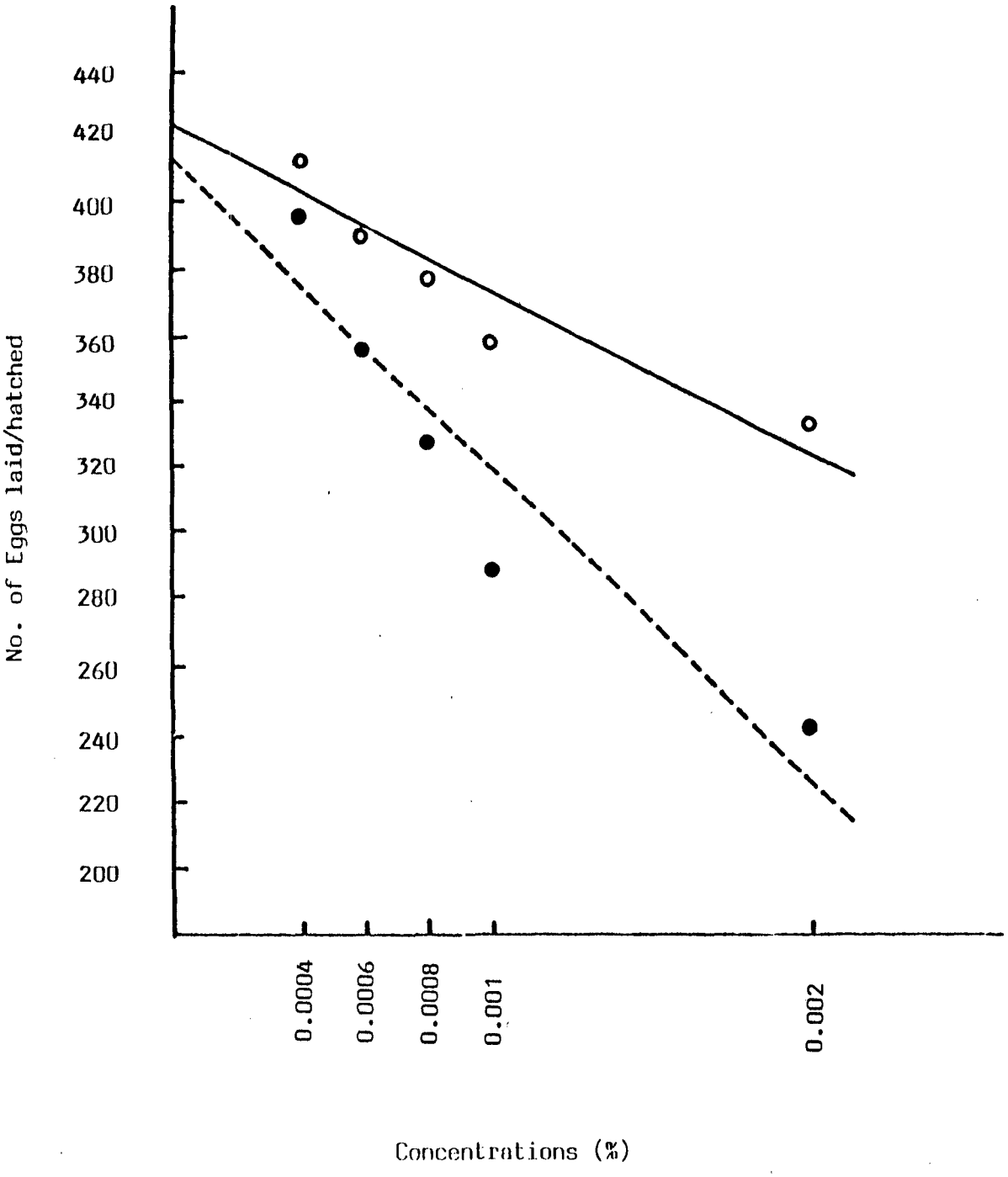

Fig. 1. Linear reduction in fecundity (○) and fertility (●) of *D. cingulatus* females emerged from 4th instar treated nymphs following topical application of different concentrations of acephate.

the nymphs, the average egg production by the females dropped significantly by 11.03% (t=3.3678, P<0.05), 15.73% (t=3.8759, P<0.05) and 21.83% (t=4.0679, P<0.05), respectively, as compared to control-I.

Like wise, the fertility of the eggs laid by these affected females also decreased linearly and showed negative correlation (Y= 413.63 - 93706.90 X, r= -0.9562, P<0.05). The hatchability of the eggs after the application of 0.0004 and 0.0006% acephate dropped insignificantly by 2.71% (t=2.0261, P<0.05) and 7.55% (t=3.2484, P<0.05), respectively, as compared to control-I (Table-1). Whereas on the application of the higher concentrations (0.0008, 0.001 and 0.002%), the fertility of the eggs dropped significantly by 12.02% (t=4.2266, P<0.01), 18.89% (t=4.5093, P<0.01) and 25.86% (t=5.5020, P<0.01), respectively, as compared to control-I (Table-1).

1.2. Effects of Topical Application of Sublethal Concentrations of Acephate on The 5th Instar Nymphs of *Dysdercus cingulatus* Fabr.

1.2.1. Mortality, Moulting and Longevity

In the first set, 100 nymphs were topically treated with 1 µl of acetone, the total nymphal mortality up to adult emergence was 3% which was only 1% more than that of untreated control-II. In the second set, similar number of 5th instar (one day old) nymphs was treated with the lowest concentration of acephate (0.0004%), only 2 nymphs died during the same instar, whereas, all the survived nymphs were as active as the control. In the third set, the topical application of 0.0006% acephate resulted in 9 deaths during the same instar, whereas, 3 nymphs could not cast off their exuviae and died due to incomplete nymphal-adult moulting. Thus, the total adult emergence was 9% less as compared to control-I (Table-2). Further, out of the 88% emerged adults, 7.9% were with malformed wings. In the fourth set of experiment, when 0.0008% acephate was applied on 100 nymphs, 18 died during the same instar and 2 expired during the nymphal-adult moulting. Thus, the total

loss upto adult emergence was 17% more as compared to control-I (Table-2). Among the adults which emerged from the survived 5th instar nymphs, 5.4% developed malformed wings. In the fifth set, following the topical application of 0.001% acephate, the mortality was 21% within the same instar and 5 nymphs died during the nymphal-adult ecdysis. Consequently the total adult emergence was 23% less as compared to the control-I (Table-2). Among the emerged adults, 9.1% were with malformed wings. In the sixth set of 100 nymphs treated with 0.002% acephate, 30 nymphs died during the same instar, whereas, 9 nymphs could not cast off their exuviae and died during the process of nymphal-adult ecdysis, leading to total nymphal mortality up to adult emergence by 36% more the the control-I (Table-2). Among the emerged adults, 14.3% had malformed wings. The average survival duration of 5th instar nymphs was enhanced by 27%, whereas, the life span of adult males and females that emerged from the 5th instar treated nymphs was 32.9 and 18.9% more than control-I (Table-25).

1.2.2. Fecundity and Fertility

Following the emergence of the adults from each treated set of nymphs, the males were paired with the virgin females of their respective age and set. Then the average egg production was dropped, which was concentration based, and the decrease was linear with negative correlation (Y= 418.04 - 30258.62 X, r= - 0.9689, P<0.001, Fig.1). Following the topical application of 0.0004, 0.0006, 0.0008 and 0.001% acephate /5th instar nymphs, the fall in oviposition of the affected females was 1.91% (t=1.1146, P>0.05), 3.11% (t=1.5888, P>0.05), 6.94% (t=2.1715, P>0.05) and 9.09% (t=2.4777, P>0.05), respectively, as compared to control which were statistically insignificant. It was only 0.002% which inhibited fecundity significantly by 13.64% (t=3.4899, P<0.02) as compared to control-I (Table-2).

As regards the hatchability of the eggs laid by the affected females (emerged from the survived nymphs treated by different concentrations of acephate) except in case of 0.0004% acephate, it decreased linearly with negative correlation coefficient (Y= 412.81 - 69137.93 X, r= - 0.9465, P<0.05, fig.1). However, by the topical application of the lowest concentration (0.0004%) the hatchability of the eggs

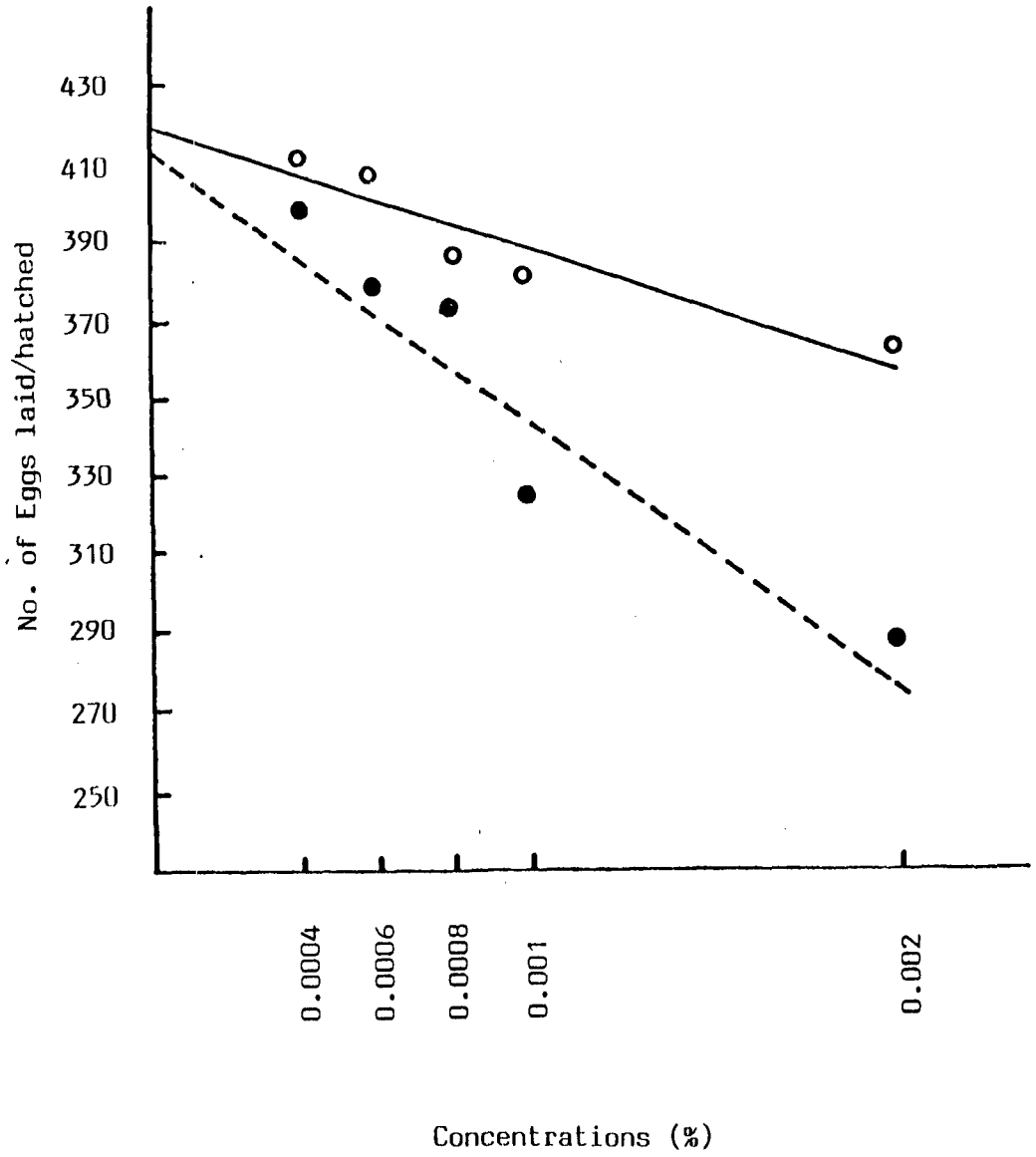

Fig. 2. Linear reduction in fecundity (o) and fertility (●) of *D. cingulatus* females emerged from 5th instar treated nymphs following topical application of different concentrations of acephate.

increased slightly by 0.94% as compared to the control (98.33%), whereas, with other concentrations of acephate the reduction in egg viability were 5.24 (t= 2.1731, P>0.05), 10.41 (t= 3.2758, P<0.05), 13.33 (t=3.1859, P<0.05) and 19.38% (t=3.9271, P<0.02), respectively, as compared to the control which were statistically significant (Table-2).

2.1. Effects of Topical Application of Sublethal Concentrations of Ethion on 4th Instar Nymphs of *Dysdercus cingulatus* Fabr.

2.1.1. Mortality, Moulting and Longevity

In the first set of 100 4th instar nymphs (one day old), topically treated with 1 µl acetone solution, there was no significant effect in terms of mortality when compared with untreated nymphs (control-II). The total nymphal mortality up to adult emergence was 4% as in untreated group. In the second set, where 100 nymphs of 4th instar were treated topically with the lowest concentration (0.0008%) of ethion, only 5 nymphs died during the same instar. The adults which emerged from the survived nymphs were quite normal and showed no malformation. In the third set, the application of 0.001% ethion resulted in death of 9 nymphs during the same instar, whereas, 2 nymphs died during the ensuing ecdysis and 3 during the 5th instar. The total nymphal mortality up to adult emergence was 10% more as compared to the control-I (Table-3). The surviving adults were active and had no malformation. In the fourth set, out of 100 nymphs treated with 0.002%, the nymphal mortality was 15 during the same instar, and 4 at the ensuing ecdysis. Thus, the total nymphal loss up to adult emergence was 16% more as compared to the control (Table-3). The survived nymphs were as active as those of control and the emerged adults had no malformation. In the fifth set, the topical application of 0.004% ethion resulted in 26% more loss within the same instar, whereas, 5 nymphs died during the next nymphal-nymphal moulting. Further, the mortality was 3 each in 5th instar and nymphal-adult ecdysis. Thus, the total loss in nymphal population up to adult emergence was 36% more as compared to the control (4%).

Among the adults which emerged from the survived treated nymphs, 8.3% had malformed wings. The survival of 4th and 5th instar nymphs was enhanced by 15.9 and 18.9%, respectively. Whereas the mean longevity of adult males and females which emerged from the treated nymphs was increased by 21 and 12%, respectively, than control (Table-26). In the sixth set, 100 nymphs of 4th instar (one day old) were treated with 0.006% ethion, then the population was highly affected, showing a drop of 40% within the same instar. The total nymphal loss up to adult emergence was 47% more as compared to the control-I (Table-3). The adult emergence was drastically blocked, decreasing to 57% by the application of 0.006% ethion. Among the adults which emerged from the survived treated nymphs, 13.4% were with malformed wings. These malformed adults were lethargic and not as competitive as those of controls. The prolongation in mean longevity of 4th and 5th instar nymphs was by 22.9 and 26%, respectively, as compared to control-I, whereas, the mean life span of adult males and females was enhanced by 32 and 19%, respectively, than control-I (Table-26).

2.1.2. Fecundity and Fertility

The adult males emerged from survived treated nymphs (affected males) were paired with affected females of the same age to record fecundity and fertility of the laid eggs. The average egg laying of the affected females by ethion also decreased linearly with increasing concentrations ($Y=395.51 - 1058301 X$, $r= -0.9663$, $P<0.001$, Fig-2). In case of 0.0008, 0.001 and 0.002% ethion, fecundity were 3.75 ($t=1.5529$, $P>0.05$), 2.5 ($t=1.0885$, $P>0.05$) and 8.0% ($t=1.9146$, $P>0.05$) less as compared to the control-I (Table-3). However, the topical application of the higher concentrations viz., 0.004 and 0.006% induced significant cessation in oviposition of the females by 13.75 ($t=2.8716$, $P<0.05$) and 15.25% ($t=3.3093$, $P<0.05$), respectively, as compared to the control-I (Table-3). Further, the commencement of oviposition by these females was delayed and the inter oviposition period of the subsequent batches of eggs were longer in comparison to the control-I.

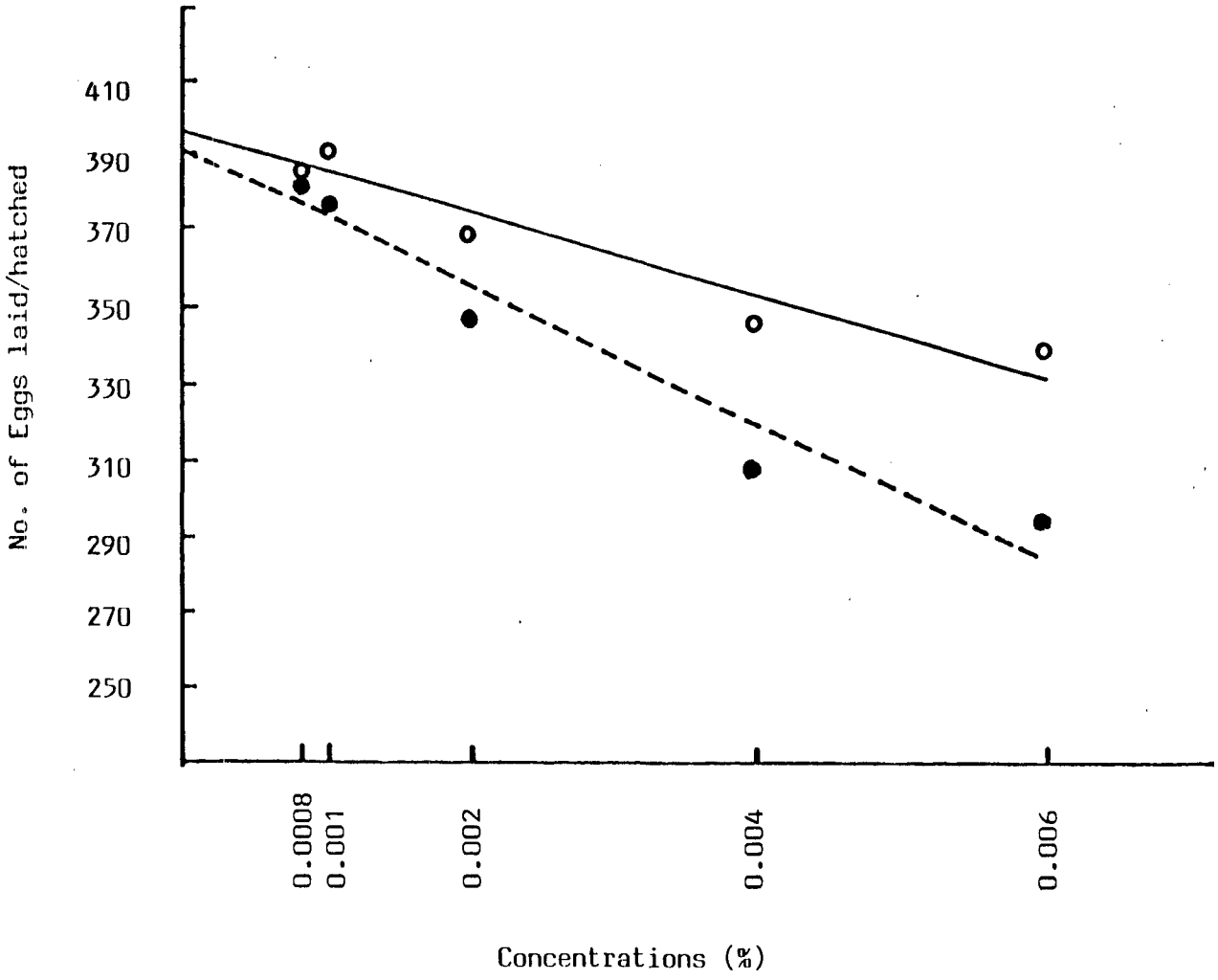

Fig. 3. Linear reduction in fecundity (○) and fertility (●) of *D. cingulatus* females emerged from 4th instar treated nymphs following topical application of different concentrations of ethion.

The fertility of the eggs laid by these affected females which survived the aforesaid concentrations of ethion also declined linearly with increasing concentrations and yielded a negative correlation (Y=390.29 - 17733.59 X, r= -0.9782, P<0.001, fig. 2). However, the two lower concentrations (i.e. 0.0008 and 0.001%/nymph) resulted in a slight increase (insignificant) in egg viability by 1.71 (t=0.8293, P>0.05) and 0.44% (t=0.9058, P>0.05), respectively, as compared to the control-I (Table-3). On the contrary, the topical application of 0.002, 0.004 and 0.006% of the present chemical caused inhibitory effect on the egg viability and resulted in 3.5 (t=2.0729, P>0.05), 7.68 (t=3.0517, P<0.05) and 11.11% (t=3.2829, P<0.05), respectively, as compared to the control-I (Table-3). The eggs were quite normal in shape, size and appearance but embryonic development did not occur and they showed pre-embryonic death.

2.2. Effects of Topical Application of Sublethal Concentrations of Ethion on 5th Instar Nymphs of *Dysdercus cingulatus* Fabr.

2.2.1. Mortality, Moulting and Longevity

In the first set, 100 nymphs of 5th instar were treated with 1 µl of acetone solution only (control-1), the total nymphal mortality up to adult emergence was insignificant (4%) which was 2% more as compared to untreated nymphs (control-II). The nymphs which survived the treatment were quite active and healthy. In the second set, 100 nymphs of the 5th instar were treated with 0.0008%, the total loss up to adult emergence was 1% less than that of the control (Table-4). The adults which emerged from the treated nymphs were normal in behaviour and physical appearance. In the third set, the topical application of 0.001% ethion resulted in 7% loss within the same instar, whereas, 4 nymphs died during the nymphal-adult ecdysis. The total drop in adult emergence was 7% more as compared to the control-I. Among the adults which emerged from the survived nymphs, 3.9% had malformed wings. The average longevity of either nymphal or adult stage were unchanged. In the fourth set having 100 nymphs, treated with 0.002% ethion, the

mortality was 9% more during the same instar as compared to the control-I, whereas, 3 nymphs could not survive due to incomplete nymphal-adult ecdysis. The total fall in adult emergence was 12% more as compared to the control-I (Table-4). The survived 5th instar nymphs were normal in behaviour but among the adults which emerged from these nymphs, 6.9% were with malformed wings. In the fifth set, each of the 5th instar nymphs were applied with 0.004% ethion, 22 nymphs died during the same stage, whereas, 6 lost their lives due to failure of moulting. The total loss in adult emergence was 24% more as compared to the control-I (Table-4). The adults which emerged from the survived nymphs, 10.4% had malformed wings and these adults were lethargic and could not compete with the opposite sex. The prolongation in mean longevity of 5th instar nymphs which survived the treatment was 14.5% more as compared to the control-I. Whereas the mean longevity of adult males and females was enhanced by 28.9 and 21.9%, respectively, as compared to the control-I (Table-26). In the sixth set, the topical application of 0.006% ethion resulted in 25% more deaths within the same instar as compared to control-I, whereas, 6 nymphs could not cast off their exuviae and died due to incomplete moulting (Table-4). The adult emergence was drastically blocked by the action of 0.006% ethion showing 30% decrease as compared to the control-I. Among these adults 14.24% had malformed wings. These morphologically abnormal adults were not as active as the normal adults and they could not compete successfully with the opposite sex. The mean survival of 5th instar nymphs was prolonged by 37%, however, the average survival of adult males and females was enhanced by 41 and 31%, respectively, than control-I (Table-26).

2.2.2. Fecundity and Fertility

The males which were healthy and normal in appearance were allowed to mate with the females of their respective sets. The average egg laying by the females that emerged from the treated 5th instar nymphs and mated with their respective male partners following the topical application of 0.001, 0.002, 0.004 and 0.006% ethion, decreased linearly and showed a negative correlation ($Y=403.97 - 9698.84 X$, $r= - 09319$, $P<0.05$, fig 2). However, with respect to the lowest concentration (0.0008%) there was enhancement in egg deposition by 1.99%

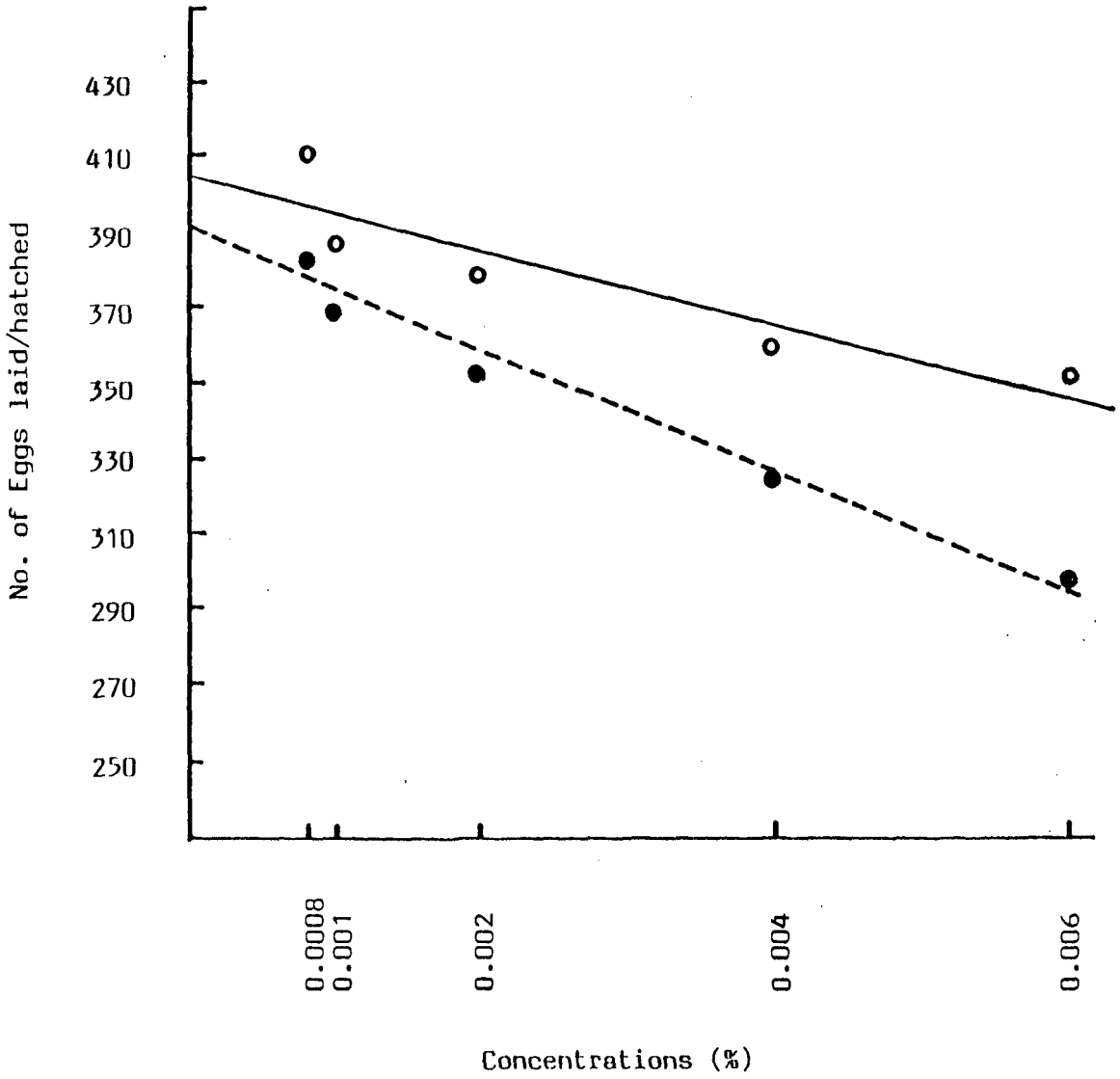

Fig. 4. Linear reduction in fecundity (○) and fertility (●) of *D. cingulatus* females emerged from 5th instar treated nymphs following topical application of different concentrations of ethion.

(t=1.0839, P>0.05) as compared to the control-I (Table-4). But the application of 0.001, 0.002 and 0.004% ethion /5th instar nymphs caused 3.97 (t=1.2903, P>0.05), 5.96 (t=1.9201, P>0.05) and 10.92% (t=2.4982, P>0.05) decrease in egg laying,respectively, as compared to control-I, which were statistically insignificant (Table-4). However, there was significant (12.9%, t=2.9054, P<0.05) reduction in average oviposited eggs in case of topical application of 0.006% ethion as compared to control-I.

Similarly, the hatching of the eggs laid by these affected females which emerged out from the survived treated nymphs declined linearly and yielded a negative correlation with the increase in concentrations (Y=390.79 - 16212.36 X, r= - 0.9872, P<0.001, Fig..2). The hatchability of the eggs laid by the females which emerged out from the survived treated nymphs following the application of 0.0008, 0.001 and 0.002% ethion, dropped by 1.55, 3.42 and 5.63% (t=1.5658, 2.3987 and 2.3702, P>0.05), respectively, as compared to the control-I, which were statistically insignificant. However, the topical application of 0.004 and 0.006% ethion /5th instar nymphs resulted in significant cessation in egg viability by 8.54% (t=3.2748, P<0.05), respectively, as compared to the control-I (Table-4). The eggs which were laid by these affected females were normal in size and shape. Some eggs initially showed embryonic development and turned yellowish in colour, but finally they could not hatch and eventually started shrinking and turned black.

3.1. Effects of Topical Application of Sublethal Concentrations of Dichlorvos on 4th Instar Nymphs of *Dysdercus cingulatus* Fabr.

3.1.1. Mortality, Moulting and Longevity

In the first set, 100 nymphs of 4th instar were treated with 1 µl acetone only, the total nymphal mortality up to adult emergence was only 2% more as compared to untreated nymphs (Table-5). All survived nymphs were active and successfully transformed to adults. In the second set, when 100 nymphs were topically treated

with 0.002% of dichlorvos, 8 nymphs died during the same instar, whereas, 2 nymphs suffered mortality during the following ecdysis (nymphal-nymphal). The survived nymphs were active and did not show any sign of morphological deformity. Out of these nymphs, adults emergence was 6% less than that of the control-I (Table-5). In the next set of 100 nymphs (4th instar) following the application of 0.004% dichlorvos, 13 nymphs died in the same instar and 3 during the moulting to next nymphal instar. Subsequently, 1 nymph died during the nymphal-adult ecdysis. Thereby, the total nymphal loss was 17% up to adult emergence which amounted to 12% drop in adult emergence as compared to the control-I. Out of these adults, 5.3% had malformed wings. In another set of 100 nymphs (4th instar) after topical application of 0.006% dichlorvos, 22 nymphs died within the same instar and subsequently 6 could not survive during the ecdysis (4^{th}-5^{th}). The total nymphal loss up to adult emergence was 25% more as compared to control-I (Table-5). Among adults which emerged out from the survived nymphs, 9.4% were with malformed wings. In case of nymphs which were applied with 0.008% dichlorvos, 30 nymphs suffered mortality during the same instar, whereas, 6 could not cast off their exuviae completely and lost their life (at the nymphal-nymphal moulting). Further, 5 nymphs died during the 5^{th} instar, whereas, 2 suffered mortality during the nymphal-adult moulting. The adult emergence dropped by 38% as compared to the control-I (Table-5), and out of these emerged adults, 7.8% had malformed wings. In the sixth set, the strongest concentration of the present series resulted in 37% more mortality in the same instar in comparison to the control, whereas, 5 nymphs died during the ensuing ecdysis and later mortality of 3 nymphs occurred in the 5^{th} instar. Again 5 nymphs succumbed to incomplete nymphal-adult ecdysis. Thus, the total loss of treated nymphs up to adult emergence was 49% more as compared to the control-I. The number of malformed adults emerged from the survived nymphs following application was 13.1%. The increase in average longevity of 4^{th} and 5^{th} instar nymphs which survived the treatment was 27 and 14%, whereas, the mean longevity of adult males and females which emerged from the treated nymphs was 15% and 11% greater than control-I (Table-27).

3.1.2. Fecundity and Fertility

The emerged males of each set of treated nymphs which were physically healthy and normal in their activities were allowed to mate with the virgin females of their respective sets. The average egg laying of the affected emerged females following the topical application of the aforesaid concentrations once again declined linearly and yielded a negative correlation with relatively higher concentrations (Y=388.62 - 5357.14 X, r= - 0.8521, P<0.05, fig 3). On the application of the lower concentrations (i.e., 0.002% and 0.004%), the mean fecundity of the affected females reduced by 2.31 and 4.1%, respectively, which were statistically insignificant (t=1.1379 and t=1.7056, P>0.05) as compared to the control-I (Table-5). However, the application of the stronger concentrations (0.006, 0.008 and 0.01%) of dichlorvos resulted in 14.87, 8.97 and 13.08% decrease in egg production (t=3.3081, 2.4544, and 2.5440, P<0.05), respectively, as compared to the control-I (Table-5). The commencement of oviposition was late and the interoviposition period of the subsequent batches of eggs were also longer in comparison to the control-I.

Similarly, the viability of the eggs laid by the affected females was also reduced linearly (Y=393.95 - 11257.14 X, r= - 0.9508, P<0.001, Fig. 3) with negative correlation. However, the application of the lower concentrations (0.002 and 0.004%) of dichlorvos exhibited slight stimulatory effect on hatching by 0.74 (t=0.9414, P>0.05) and 0.99% (t=1.2616, P>0.05) as compared to the control-I, which were statistically insignificant (Table-5). Conversely, the topical application of the higher concentrations (0.006, 0.008 and 0.01%) caused significant inhibitory effect on hatching showing 5.14 (t=2.4148, P>0.05), 12.25 (t=2.6763, P<0.05 and 15.32% (t=3.2630, P<0.05) drop, respectively, in egg viability as compared to the control-I (Table-5). The non-viable eggs appeared normal in shape and size and initially showed normal development bearing pale colour. But just before hatching, some eggs shrunk and changed to light black colour. This established inhibition in embryonic development and subsequent death of the embryo.

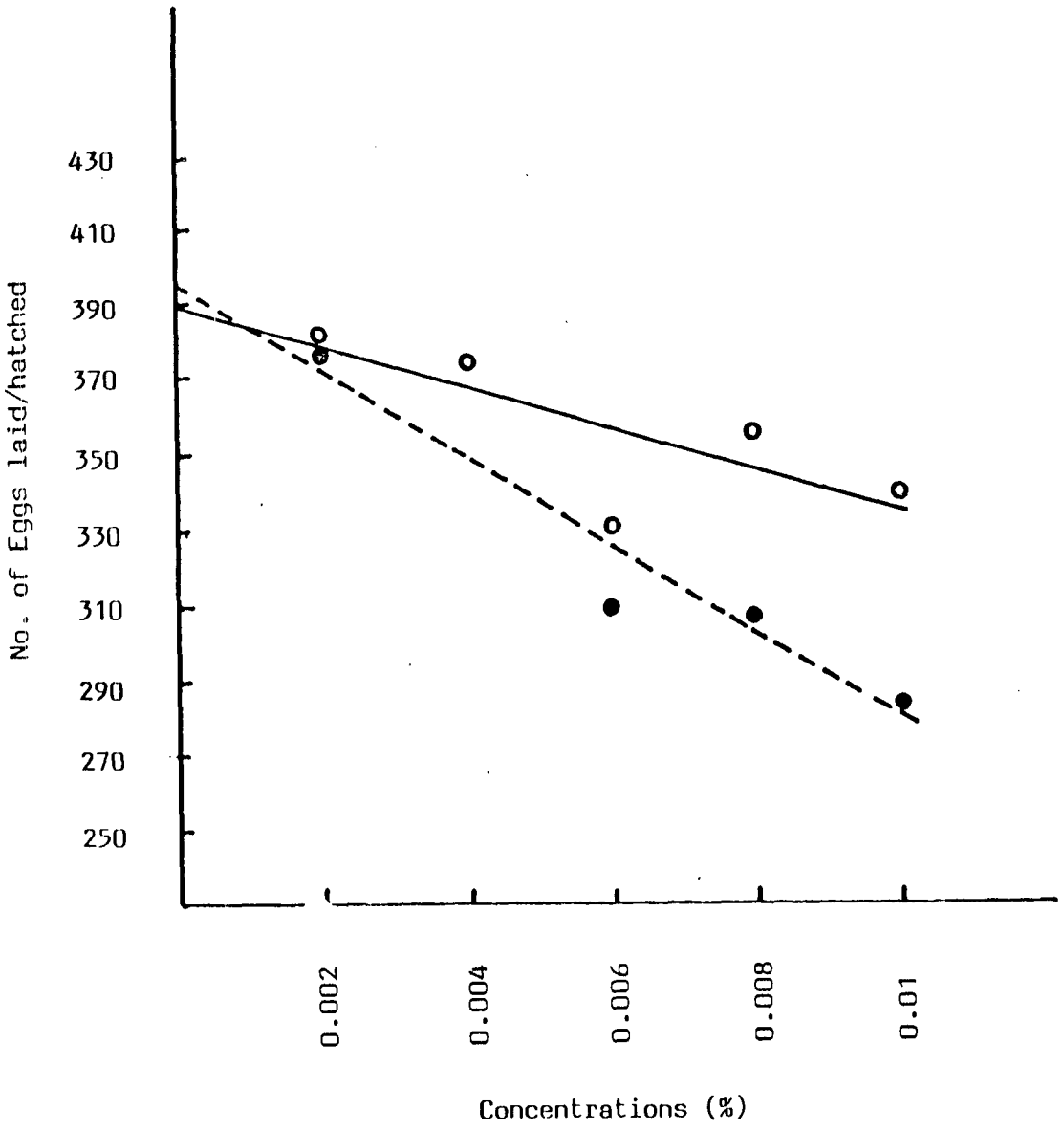

Fig. 5. Linear reduction in fecundity (○) and fertility (●) of *D. cingulatus* females emerged from 4th instar treated nymphs following topical application of different concentrations of dichlorvos.

3.2. Effects of Topical Application of Sublethal Concentrations of Dichlorvos on the 5th Instar Nymphs of *Dysdercus cingulatus* Fabr.

3.2.1. Mortality, Moulting and Longevity

In the first set of 100 nymphs, when each was individually treated with 1 µl acetone only, the total nymphal mortality upto adult emergence was 3%, which was 2% more as compared to untreated nymphs of same stock and age. All the adults which emerged from the treated survived nymphs were normal and active like those of untreated nymphs. In the second set, the topical application of the lowest concentration (i.e. 0.002%) of dichlorvos could not cause significant mortality either within the same instar or up to adult emergence. The total nymphal mortality up to adult emergence was only 3% more as compared to control-1. All the emerged adults were active and normal morphologically. In the third set, when each nymph was treated with 0.004% dichlorvos, 7 died during the same instar, whereas, mortality of 2 such nymphs occurred at the following nymphal-adult ecdysis. The total loss up to adult emergence was 6% more as compared to control-I (Table-6). In the fourth set, treated by 0.006% dichlorvos/nymph, 16 treated nymphs suffered mortality during the same instar, whereas, 7 succumbed to incomplete nymphal-adult ecdysis. Thus, the total nymphal mortality upto adult emergence was 20% more as compared to control-1 (Table-6) which was statistically significant. Out of the adults which emerged from the survived treated nymphs, 6.3% adults were with malformed wings. The mean survival of both nymphs and adults remain unchanged. In the fifth set, when each nymph was applied with 0.008% dichlorvos, 27 died within the same instar, whereas, 3 could not cast off their exuviae completely and succumbed to incomplete moulting. Adult emergence following the application of 0.008% dichlorvos, dropped by 27% as compared to the control-I. Out of the emerged adults, 11.2% were with malformed wings. In the sixth set, the topical application of 0.01% dichlorvos/nymph resulted in 29% more loss within the same instar as compared to the control-I and only one nymph died during the nymphal-adult moulting. The total nymphal loss up to adult emergence was significantly 29% more as compared to the control-I (Table-6). On emergence, 12.7% adults were

with malformed wings. The mean longevity of 5th instar nymphs was enhanced by 21.7%, whereas, the average survival period of adult males and females was increased by 27 and 17%, respectively, as compared to the control-I (Table-27).

3.2.2. Fecundity and Fertility

The males which looked healthy and normal were paired with the virgin females of their respective sets. The average egg production by the females which emerged out from the survived treated nymphs following the topical application of the aforesaid concentrations dropped linearly (Y=396.33 - 4099.99 X, r= - 0.9849, P<0.001, fig. 3) and yielded a negative correlation. Following the topical application of 0.002, 0.004, 0.006 and 0.008% dichlorvos /5th instar nymph, the average egg production by the females dropped insignificantly by 2.03, 3.04, 6.08 and 7.09% (t=1.0629, 1.3946, 1.7841 and 2.1896, P>0.05), respectively, as compared to the control-I (Table-6). However, the topical application of the strongest concentration (0.01%) of dichlorvos /5th instar nymph resulted in a 10.89% (t=2.7088, P<0.05) reduction in egg production which was statistically significant as compared to the control-I.

As regards the fertility of the eggs laid by these affected females, it also dropped linearly and yielded a negative correlation coefficient with increase in concentration of the chemical (Y=391.67 - 7799.99 X, r= - 0.9532, P<0.001, fig. 3). The average fertility of the eggs, laid by the affected females following the application of 0.006 and 0.008% concentration of dichlorvos /nymphs dropped insignificantly by 1.83 (t=1.9414, P>0.05) and 5.97% (t=2.3179, P>0.05), respectively, as compared to the control-I, whereas, the average hatchability of the eggs laid by the affected females following the topical application of the strongest concentration (i.e. 0.01% /nymph) dropped by 10.91% (t=3.0307, P<0.05) as compared to control-I (Table-6). On the contrary, the application of the lower concentrations i.e. 0.002 and 0.004% dichlorvos /nymph affected in somewhat stimulatory manner the hatching of the eggs and insignificantly enhanced egg viability by 0.19 (t=0.9058, P>0.05) and 0.42% (t=1.1166, P>0.05), respectively,

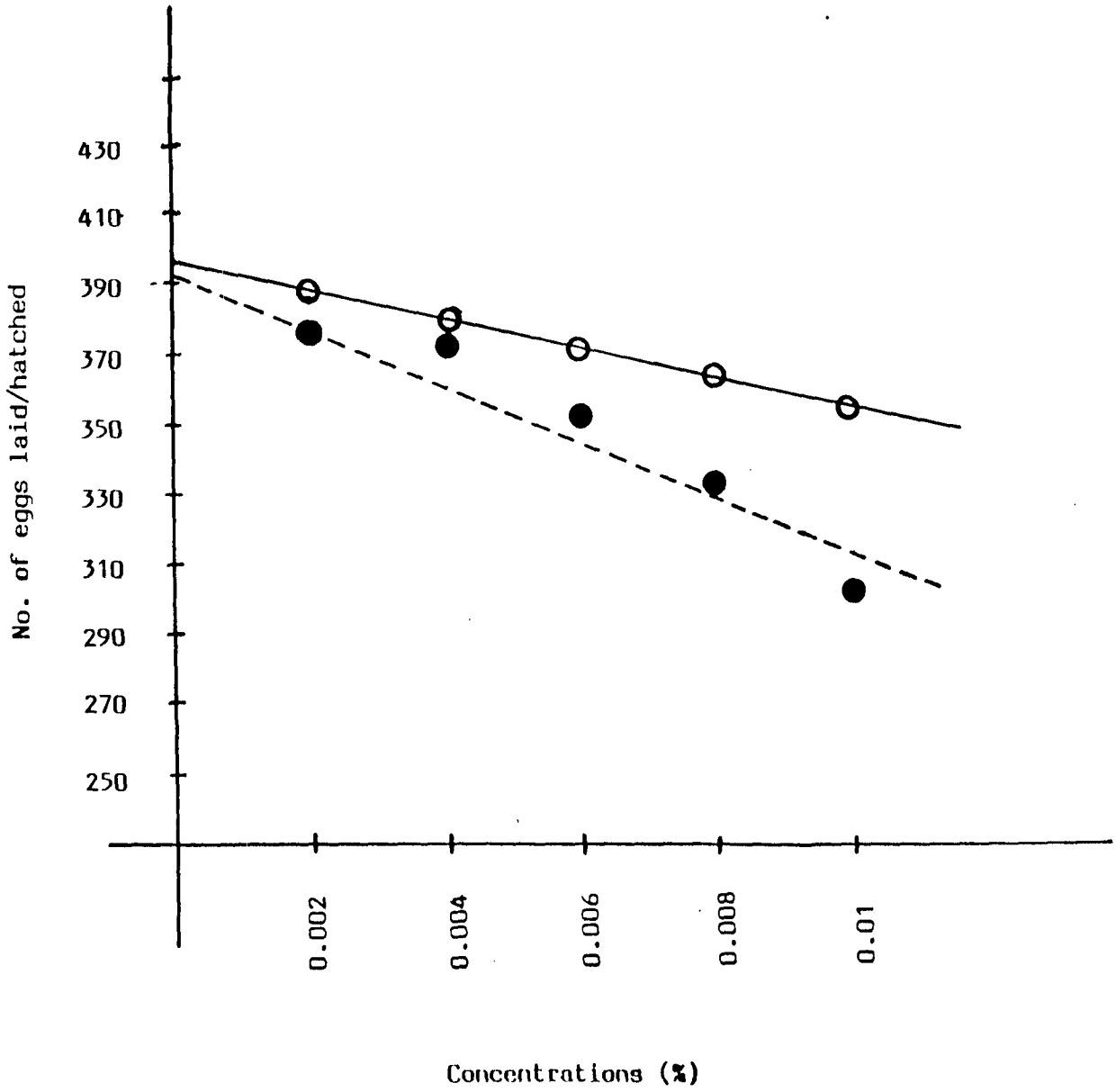

Fig. 6. Linear reduction in fecundity (○) and fertility (●) of *D. cingulatus* females emerged from 5th instar treated nymphs following topical application of different concentrations of dichlorvos.

(Table-6). All the eggs which were laid by these affected females were normal in shape, size and appearance.

4.1. Effects of Topical Application of Sublethal Concentrations of Furadan on 4th Instar Nymphs of *Dysdercus cingulatus* Fabr.

4.1.1. Mortality, Moulting and Longevity

In the first set, 100 nymphs were treated topically with 1 µl acetone, the total nymphal mortality up to adult emergence was only 4% which was 2% more as compared to untreated nymphs (control-II). As there was no significant difference between control-I and control-II nymphs, therefore, the effect of each concentration was compared with control-I only, so as to nullify the effect of acetone. The adults which emerged from such nymphal stock were morphologically normal. In the second set, the topical application of the lowest sublethal concentration of furadan (0.0002%) gave 7% mortality during the 4th instar itself, however, none died during the next instar as well as nymphal-nymphal moulting. Thus, the total nymphal mortality up to adult emergence was 4% more as compared to control-I. In the third set of 100 nymphs, when each was applied with 0.0004% furadan, 15 died during the same instar and 3 during the 5th instar. There was no death at either nymphal-nymphal or nymphal-adult moulting. Thus, the total nymphal mortality was 14% more than the control-I (Table-7). Out of the adults which emerged from the survived nymphs, 5.8% were with malformed wings. In the fourth set, each nymph was topically treated with 0.0006% furadan, out of which 20 died within the same instar, whereas, 4 suffered mortality during the nymphal-nymphal ecdysis. Further, mortality of 4 nymphs occurred during the 5th instar and one died during the nymphal-adult moulting so that there was 25% more nymphal loss up to transformation to adult stage as compared to control-I. Out of the emerged adults, 7.8% of them were with malformed wings. In the fifth set of 100 nymphs, when each was applied with 0.0008% furadan, the mortality within the same instar was 26% more than that of the control. Aside, 6 nymphs lost their lives during the moulting to

5th instar. The total nymphal mortality up to adult emergence was 40% more as compared to control-I (Table-7). The percentage of malformed adults emerged from treated nymphs was 11.5. The mean nymphal as well as adult longevity was almost unchanged. In the final (sixth) set, the topical application of 0.001% furadan/nymph caused 40% more deaths during the 4th instar as compared to control-I, whereas, 4 nymphs succumbed to next moulting and 10 died during the 5th instar. Aside, 2 nymphs could not cast off their exuviae and died due to incomplete nymphal-adult ecdysis. Therefore the total fall in adult emergence was 55% as compared to control-I (Table-7). Out of the emerged adults from the affected survived nymphs, 14.5% were with malformed wings. The mean nymphal duration of 4th and 5th instar was 7.1 and 6% less than control-I, whereas, the decrease in survival of adult male and female emerged from the treated nymphs was 14 and 8.2%, respectively, compared to control (Table-28).

4.1.2. Fecundity and Fertility

The healthy adult males (affected) were allowed to mate with the virgin females of their respective sets. The average egg laying of the affected females declined linearly with increasing concentrations ($Y=387.71 - 190428.37 X$, $r= -0.9918$, $P<0.001$, fig.) with negative correlation. The average fecundity of such females with respect to 0.0002% furadan dropped by 6.12% ($t=2.3100$, $P>0.05$) as compared to control-I. However, the topical application of 0.0004, 0.0006, 0.0008 and 0.001% furadan/4th instar nymph, decreased oviposition significantly by 13.03 ($t=3.2532$, $P<0.05$), 27.13 ($t=4.8312$,$p<0.02$), 38.03 ($t=5.3533$, $P<0.01$) and 48.94% ($t= 6.3873$, $P<0.01$), respectively, as compared to control-I (Table-7). The application of the lowest concentration (viz., 0.0002%) did not have any effect on commencement of oviposition, however, the application of higher concentrations prolonged the onset of oviposition by the females of the treated nymphs as compared to the control-I. Further, the intervals between oviposition of subsequent batches of eggs were also longer as compared to control-I.

Similarly, the fertility of the eggs laid by the affected females following the topical application of the aforesaid concentrations also declined linearly with the

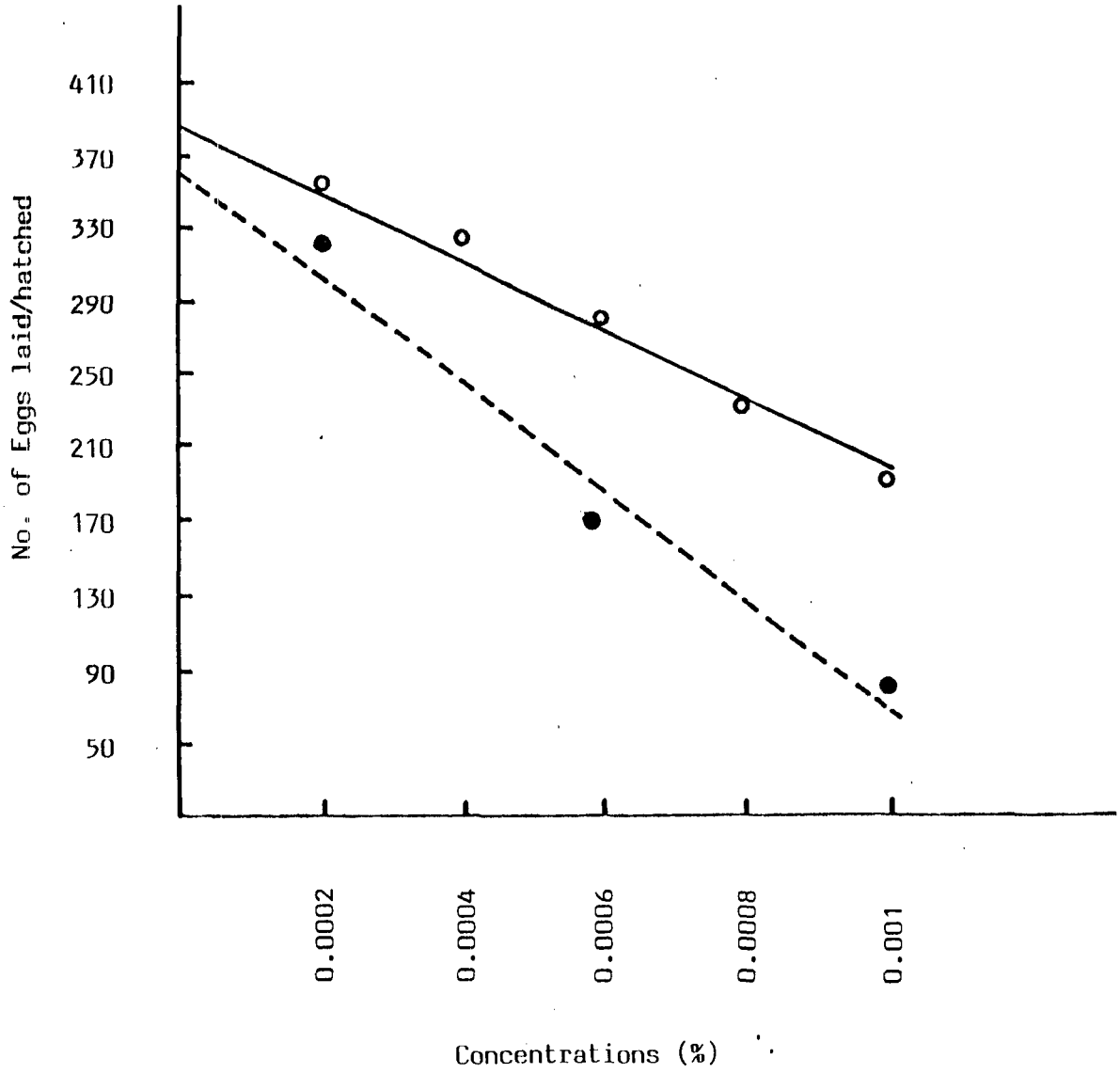

Fig. 7. Linear reduction in fecundity (○) and fertility (●) of *D. cingulatus* females emerged from 4th instar treated nymphs following topical application of different concentrations of furadan.

relatively stronger concentrations (Y=365.95 - 297571.43 X, r= - 0.9943, P<0.001). Following the topical application of (0.0002% furadan/ nymph), the mean hatching dropped insignificantly by 6.14% (t=2.4450, P> 0.05) as compared to control-I. But, the application of 0.0004, 0.0006, 0.0008 and 0.001% furadan per nymph proved to be a significant inhibitor in egg viability, which were 23.06 (t=3.8380, P<0.02), 35.39 (t=5.1189, P<0.01) 42.99 (t=5.6678, P<0.01) and 55.40% (t=6.0486, P<0.01) less, respectively, as compared to control-I (Table-7). Although, the shape of the eggs was quite normal, their size became smaller as compared to the control-I.

4.2. Effects of Topical Application of Sublethal Concentrations of Furadan on 5th Instar Nymphs of *Dysdercus cingulatus* Fabr.

4.2.1. Mortality, Moulting and Longevity

In the first set, when each of 100 nymphs was treated with 1 µl acetone solution, subsequently 6 nymphs died up to adult emergence as against 5 deaths in untreated set of control. Following the application of 0.0002% furadan/nymph (set two), the mortality was 8 within the same instar and 2 at the nymphal-adult moulting, resulting in total loss of 4% more in adult emergence as compared to control-I, (Table-8). Among the adults which emerged from the survived nymphs, 3.1% were with malformed wings. After the application of 0.0004% furadan/nymph (set three), 10 nymphs died within the same instar, whereas, 4 suffered mortality at the nymphal-adult ecdysis. The total nymphal loss up to adult emergence was 8% more than that of control-I (Table-8). Out of the emerged adults from the survived treated nymphs, 5.1 were with malformed wings. In set four, the topical application of 0.0006% furadan/nymph gave 15% more mortality within the same instar and that of 4 during the nymphal-adult ecdysis. Thus, the total death toll up to adult emergence was 16% more as compared to control-I. The percentage of malformed adults emerged from survived nymphs was 8.7. The mean longevity of nymphs as well as that of adults remain unchanged. Following the application of 0.0008% furadan/nymph (set five) to 100 nymphs, 25 suffered mortality during the present

instar, whereas, 7 could not cast off their exuviae completely and died. The total loss in adult emergence was 26% more as compared to control-I. Following the emergence, 7.3% adults were with malformed wings. Further in set six, the topical application of the strongest sublethal concentration (0.001%) of furadan/nymph caused 29% more deaths in comparison to control-I, whereas, 11 nymphs succumbed to incomplete nymphal-adult moulting. The total loss of nymphs up to adult emergence was 37% more than that of control-I. The percentage of adults bearing malformed wings was 13.4%. The average longevity of 5th instar nymphs which survived the treatment was 11.1% more, whereas, the life span of adult males and females which emerged from the treated nymphs was 6.9 and 11.8% short, respectively, than control-I (Table-28).

4.2.2. Fecundity and Fertility

Following the emergence of adults from survived nymphs, healthy and active males of each concentration were mated with the virgin females of their respective age and set. The average egg laying of these females affected by the aforesaid concentrations of furadan dropped linearly with relatively higher concentrations ($Y=381.29 - 163571.43 X$, $r= - 0.9881$, $P<0.001$, Fig. 4)

The mean egg laying of the females, which emerged from the survived nymphs treated with 0.0002% furadan dropped by 4.99% which was statistically insignificant ($t=2.0996$, $P>0.05$) as compared to the control-I (Table-8). Whereas the egg production of the affected females with respect to 0.0004, 0.0006, 0.0008 and 0.001% furadan per 5th instar nymphs dropped significantly by 19.95 ($t=4.0515$, $P<0.01$), 28.35 ($t=4.9713$, $P<0.01$), 34.12 ($t=5.1041$, $P<0.01$) and 40.94% ($t=5.8813$, $P<0.01$) respectively as compared to control-I (Table-8). The initiation of oviposition by the females affected by the higher concentrations of furadan was enhanced for a few days as compared to the control-I and the intervals between the deposition of subsequent batches of eggs were also longer. The number of eggs/batch were also less as compared to control-I.

The fertility of the eggs laid by the affected females which emerged from the treated 5th instar nymphs also declined linearly with negative correlation (Y=366.66 - 262000 X, r= - 0.9907, P<0.001, fig. 4). The topical application of 0.0002% furadan/5th instar nymphs resulted in 90.88% hatching which was 5.18% less than the control-I. However, the average hatching with respect to the application of 0.0004, 0.0006, 0.0008 and 0.001% furadan/nymph dropped by 11.14 (t=4.199, P<0.01), 27.20 (t=6.385, P<0.01), 35.10 (t=6.175, P<0.01) and 43.17% (t=7.645, P<0.001), respectively, which were statistically significant as compared to control-I (Table-8). Among the eggs which were apparently normal in shape, size and showed sign of embryonic development with normal pale colour, few started shrinking and finally became grayish in colour showing sign of abnormality.

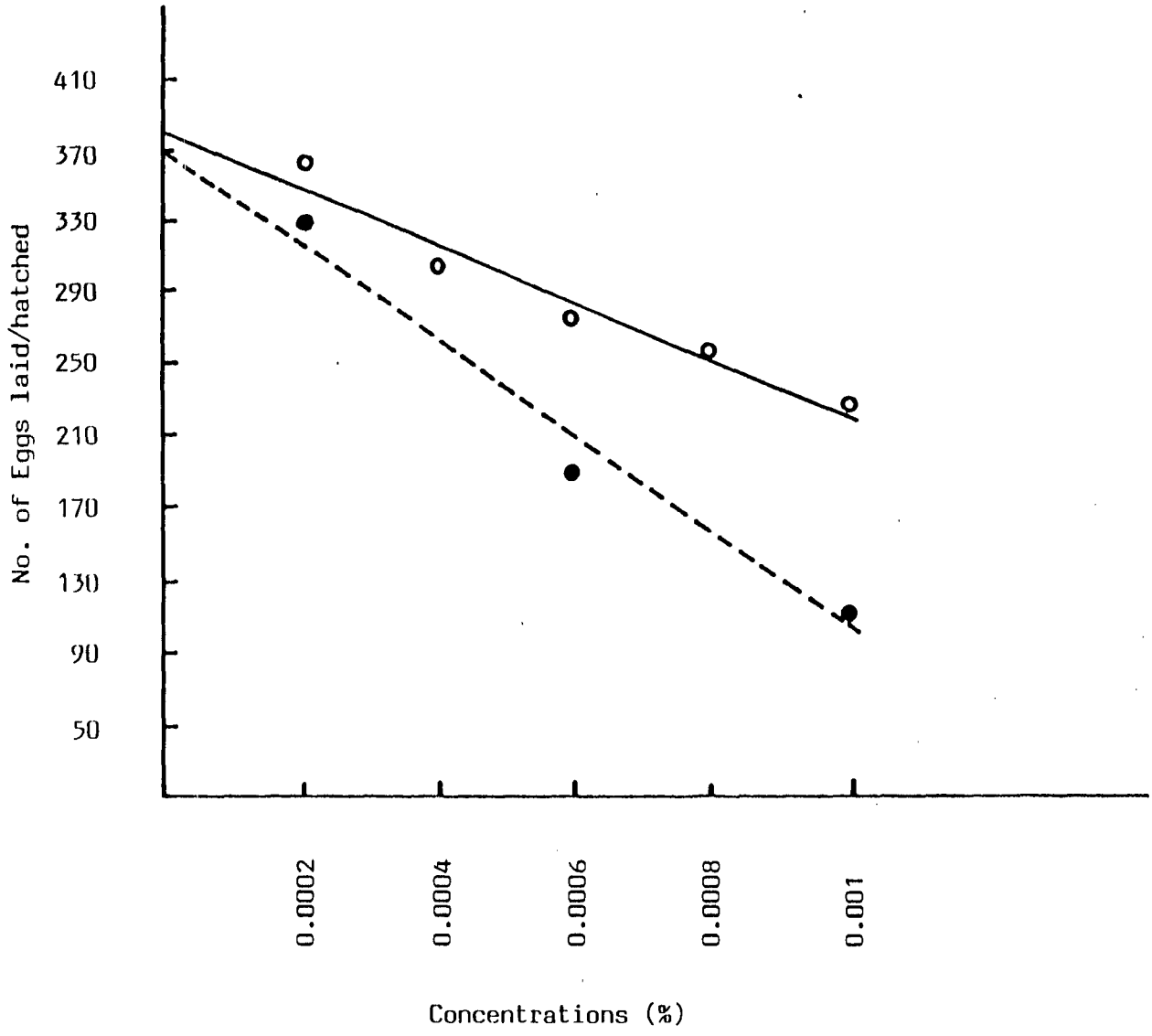

Fig. 8. Linear reduction in fecundity (○) and fertility (●) of *D. cingulatus* females emerged from 5th instar treated nymphs following topical application of different concentrations of furadan.

5.1. Effects of Topical Application of Sublethal Concentrations of Carbaryl On 4th Instar Nymphs of *Dysdercus cingulatus* Fabr.

5.1.1. Mortality, Moulting and Longevity

In the first set of experiment, 100 nymphs of 4th instar (one day old) were individually topically treated with 1 µl of acetone (solvent) only. Then the total nymphal mortality up to adult emergence was 3% which was only 1% more as compared to untreated nymphs (control-II). In the second set, each of 100 nymphs was topically applied with the lowest concentration of carbaryl (0.0005%), then 3 nymphs suffered mortality within the same instar. The total loss up to adult emergence was similar to that of the control-I. In the third set, topical application of 0.001% carbaryl was made on each nymph, then 7 nymphs died within the same instar. Subsequently, the mortality was 1 and 3 during the moulting to 5th instar and nymphal-adult ecdysis, respectively. The total nymphal mortality up to adult emergence was 8% more as compared to control-I (Table-9). Following emergence, 2.1% adults were with malformed wings. The remaining adults were active and normal in physical appearance. In the fourth set, each of the 100 nymphs was topically treated with 1 µl 0.0015% carbaryl. Then 17% death occurred during the same instar. The total loss of nymphs up to adult emergence was 17% more as compared to control-I (Table-9). Among the adults which emerged from the treated survived nymphs, 4.5% were with malformed wings. In the fifth set, the topical application of 0.002% carbaryl per 4th instar nymph resulted in 27% more loss of nymphs within the same instar as compared to the control-I. Further, mortality were 2 and 4 at the ensuing ecdysis and in 5th instar, respectively. Again 3 nymphs died during the nymphal adult ecdysis. Thus, the total nymphal loss was 37% up to adult emergence, which was 34% more as compared to control I. Out of the adults which emerged from the survived treated nymphs, 9.4% were with malformed wings. The longevity of both nymphs and adults were same as those of control-I. In the sixth set when strongest sublethal concentration (0.0025%) of carbaryl was topically applied then total nymphal mortality during the 4th instar was 36% more than that of the control-I. Further, 3 nymphs suffered mortality during the ensuing ecdysis. The

mortality during the 5th instar was 8 nymphs, whereas, 5 could not moult completely and died. The total loss up to adult emergence was 50% more as compared to control-I (Table-9). The malformation in wings was present in 14.7% emerged adults. There was no significant change in longevity of either stages (Table-29).

5.1.2. Fecundity and Fertility

The normal and healthy males which emerged from each treated set of nymphs were allowed to mate with their virgin females of their respective set and the fecundity and fertility were recorded. The average egg laying of the affected females with different concentrations of carbaryl declined linearly with increasing concentrations strength ($Y=356.81 - 37314.29 X$, $r= - 0.9683$, $p<0.001$, fig.9) and showed strong negative correlation. The topical application of 0.0005 and 0.001% carbaryl/4th instar nymphs showed 5.11 ($t=1.5085$, $p>0.05$) and 7.95% ($t=1.8367$, $p>0.05$) reduction in average egg production, respectively, as compared to control-I, which was statistically insignificant (Table-9). But, after the application of 0.0015, 0.002 and 0.0025% carbaryl /4th instar nymphs, the average fecundity dropped by 11.93 ($t=2.6840$, $p<0.05$), 17.33 ($t=3.0587$, $p<0.05$) and 28.98% ($t=3.7665$, $p<0.02$), respectively, as compared to control-I, which were statistically significant (Table-9).

Similarly, the fertility of the eggs laid by the affected females also decreased linearly ($Y=344.86 - 65885.71 X$, $r= - 0.9757$, $p<0.001$, fig.9) with higher concentrations and showed a negative correlation coefficient. The hatchability of the eggs after the application of the lowest (0.0005%) sublethal concentration decreased by 5.57% ($t=2.7647$, $p>0.05$) as compared to control-I. However, the topical application of 0.001, 0.0015, 0.002 and 0.0025% carbaryl/4th instar nymph dropped the average egg production by 9.55 ($t=3.5901$, $p<0.02$), 11.75 ($t=4.0869$, $p<0.01$), 18.93 ($t=5.1429$, $p<0.01$) and 32.59% ($t=5.5153$, $p<0.01$), respectively, as compared to control-I which was statistically significant (Table-9).

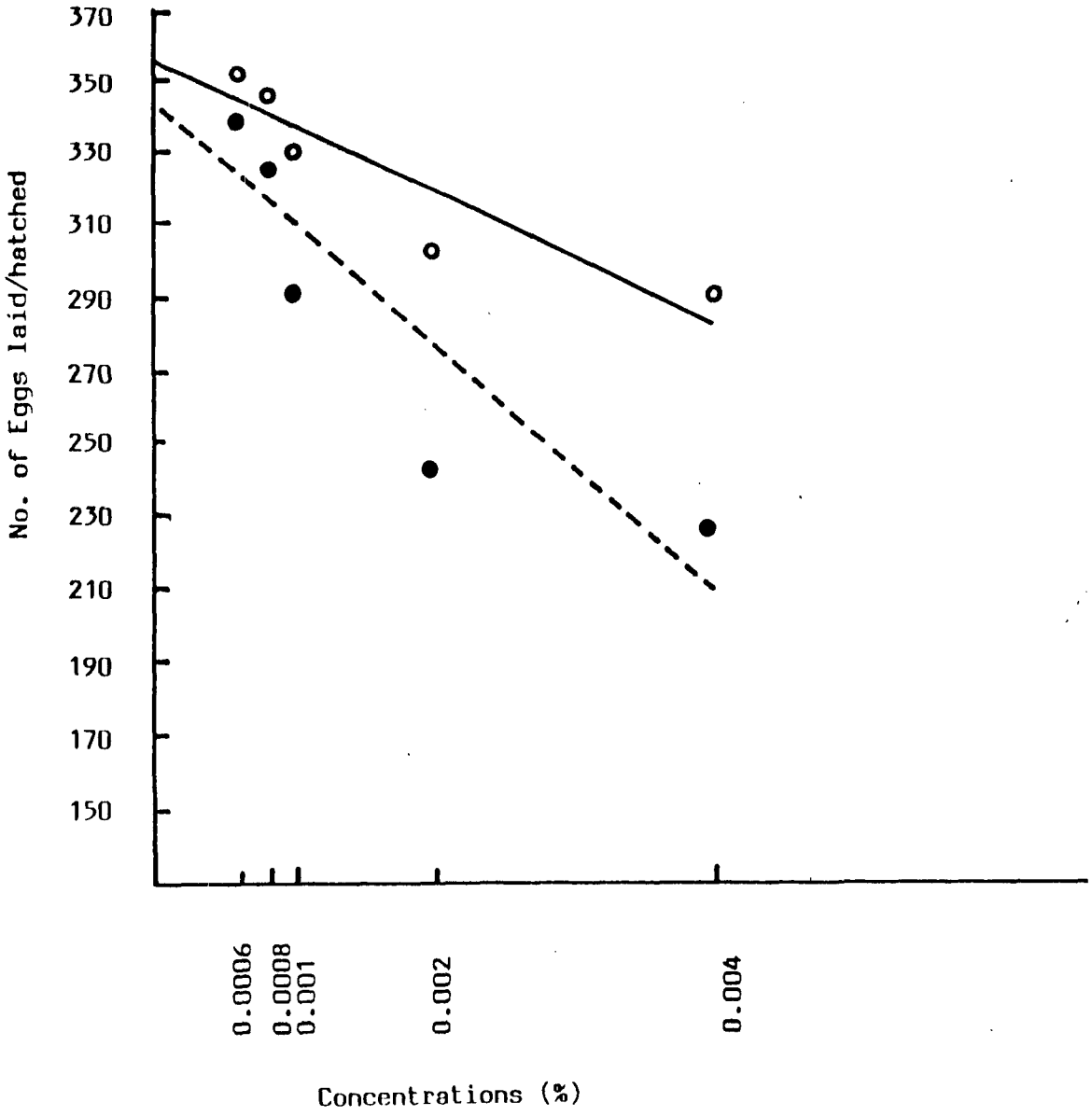

Fig. 9. Linear reduction in fecundity (○) and fertility (●) of *D. cingulatus* females emerged from 4th instar treated nymphs following topical application of different concentrations of carbaryl.

5.2. Effects of Topical Application of Sublethal Concentrations of Carbaryl on 5th Instar Nymphs of *Dysdercus cingulatus* Fabr.

5.2.1. Mortality, Moulting and Longevity

In set first of 100 nymphs of 4th instar treated with acetone (solvent) only, the total mortality up to adult emergence was 3% which was 1% less as compared to untreated nymphs (control-II). The survived nymphs as well as adults were active and normal in appearance. In set two, where 100 nymphs of 4th instar were topically treated with 0.0005% carbaryl, 4 nymphs died within the same instar and 4 lost their life due to incomplete nymphal-adult ecdysis. The total loss up to adult emergence was 5% more as compared to control-I. In set three, when each nymph was treated with 0.001% carbaryl, 5 nymphs died within the same instar, whereas, 6 suffered mortality during nymphal-adult ecdysis leading to a total loss of 11% which was 8% more than control-I (Table-10). Out of the emerged adults, 3.8% showed malformation in their wings. In the group of 100 nymphs (set four) which were topically treated with 0.0015% carbaryl /5th instar nymph, the mortality within the same instar was 10% more as compared to control-I. Further, 4 individuals died due to incomplete nymphal-adult moulting resulting in 12% more loss in adult emergence as compared to control I (Table-10). Among the adults which emerged from the treated nymphs, 6.7% had malformed wings. The effect of topical application of 0.002% carbaryl/nymph (set five) led to 15% more mortality within the same instar, whereas, 5 nymphs could not shed off their exuviae completely and died. The total nymphal mortality up to adult emergence was 18% more as compared to control-I. Out of the emerged adults, 9.8% had malformed wings. The mean nymphal duration was enhanced by 13.9% as compared to the control-I, whereas, the survival of adult males and females were increased by 14 and 9%, respectively, than control-I (Table-29). In set six, the topical application of strongest sublethal concentration (0.0025%) of carbaryl resulted in death of 32 nymphs during the same instar and 3 nymphs during moulting stage. The total fall in adult emergence was 32% more as compared to control-I (Table-10). Among the adults which emerged from the survived nymphs, 15.3% showed malformation in their wings. The survival duration

of 5th instar nymphs was prolonged by 16.3%, whereas, the average life of adult males and females was increased by 22 and 16%, respectively, as compared to control-I (Table-29).

5.2.2. Fecundity and Fertility

The normal and active males (affected) from each group of 100 nymphs, treated with each concentration of carbaryl, were allowed to mate with the virgin females of same set. The average fecundity of the females following the application of the aforesaid concentrations decreased linearly with relatively stronger concentration strength ($Y=344.38-29771.43 X$, $r= - 0.9892$, $p<0.001$) showing a negative correlation (fig.10). After the application of the lower concentrations i.e. 0.0005 and 0.001% carbaryl, the average egg production was reduced insignificantly by 3.24 ($t=1.5186$, $p>0.05$%) and 5.88% ($t=1.8411$, $p>0.05$), respectively, as compared to control-I (Table-10). Whereas the application of higher concentrations i.e. 0.0015, 0.002 and 0.0025% of carbaryl significantly lowered egg laying by 10.88 ($t=2.7764$, $p<0.05$), 15.88 ($t=3.2896$, $p<0.05$) and 22.06% ($t=4.0335$, $p<0.01$), respectively, than control-I (Table-10). Similarly, the fertility of eggs laid by affected females also reduced linearly ($Y=341.29 - 55428.57 X$, $r= - 0.9928$, $p<0.001$, fig.10). The fertility of the eggs after the application of lower concentrations (0.0005 and 0.001% carbaryl) dropped by 1.89 ($t=1.8081$, $p>0.05$) and 6.06% ($t=2.5432$, $p>0.05$), respectively, as compared to control-I. However the application of higher concentrations (i.e. 0.0015, 0.002 and 0.0025%) per 5th instar nymph, the average hatchability of the eggs laid by the female dropped significantly, which were 11.8 ($t=3.2163$, $p<0.05$%), 16.82 ($t=4.4053$, $p<0.01$) and 23.98% ($t=4.9026$, $p<0.01$) less, respectively, in comparison to control-I (Table-10).

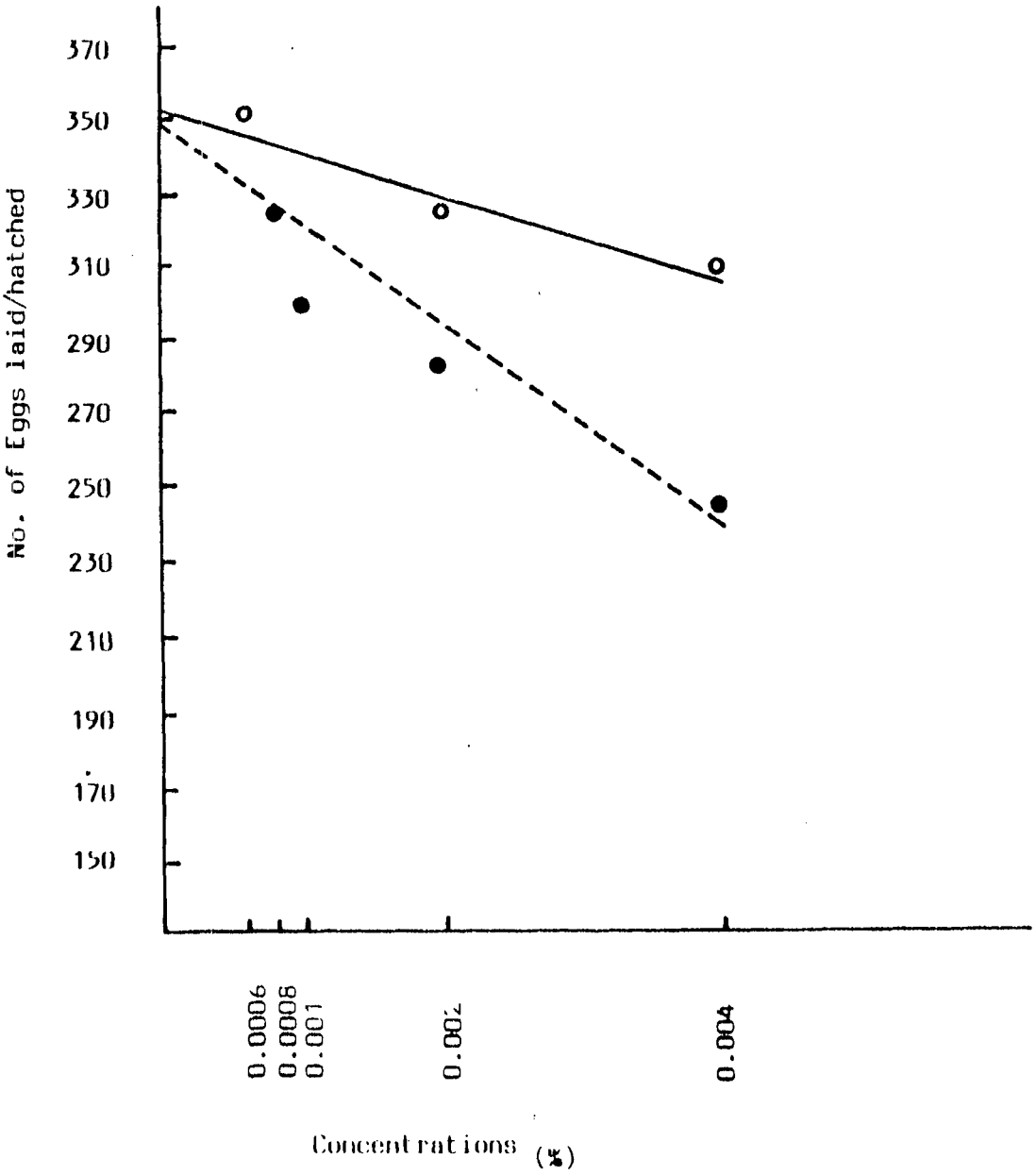

Fig. 10. Linear reduction in fecundity (o) and fertility (●) of *D. cingulatus* females emerged from 5th instar treated nymphs following topical application of different concentrations of carbaryl.

6.1. Effects of Topical Application of Sublethal Concentrations of Aminocarb on 4th Instar Nymphs of *Dysdercus cingulatus* Fabr.

6.1.1. Mortality, Moulting and Longevity

In the first set of 100 4th instar nymphs, each was treated topically with I µl of acetone only, the total mortality up to adult emergence was 6% which was 3% more as compared to control-II. The nymphs which survived the treatment were active and healthy. In the set two of 100 nymphs, which were treated with lowest concentration of aminocarb (0.0006%), there was no significant mortality either within the same instar or up to adult emergence. The total nymphal mortality up to adult emergence was only 4% more as compared to control-I. The survived nymphs were normally active and healthy. In another set of 100 nymphs (set three) when each was applied with 0.0008% aminocarb, 11 nymphs died within the 4th instar and later one and four succumbed during the next moulting and 5th instar, respectively, (Table-11). In the set fourth, in which 0.001% aminocarb was individually applied on 100 nymphs, the mortality within the same instar was 17% more as compared to control-I. Later 3 nymphs died during the 5th instar and 6 lost their life due to incomplete adult moulting. The total fall in adult emergence was 21% more as compared to control-I (Table-11). Among the adults which emerged from the treated nymphs, 5.8% had malformed wings. The nymphal as well as adult life span remained almost same as that of control-1. When each of 100 nymphs was applied with 0.002% aminocarb (set five), the death toll within the same instar was 27% more as compared to control-I, whereas, 1 lost its life during the nymphal-nymphal moulting, 7 nymphs suffered mortality during the 5th instar and 2 died during the nymphal adult ecdysis. Thus total loss up to adult emergence was 31% more as compared to control-I (Table-11). Out of the adults which emerged from the survived nymphs, 8.7% had malformed wings. The mean survival of 4th and 5th instar nymphs was increased by 9.9 and 11% respectively, whereas, the average life span of adult males and females was prolonged by 6.4 and 8.6%, respectively, as compared to control-I (Table-30). In set six, the topical application of 0.004% aminocarb resulted in 33% more deaths within the same instar, whereas, 2 nymphs

died during the moulting to next instar. Subsequently there was mortality of 9 nymphs during the 5th instar and 4 at the nymphal-adult ecdysis. Therefore, the total nymphal mortality up to adult emergence was 43% more than that of control-I (Table-11). After the emergence, 13.4% adults were with malformed wings. The remaining adults were healthy, active and normal in physical appearance. The duration of 4th and 5th instar nymphal stage was enhanced by 15 and 16%, respectively, and the survival duration of adult males and females was enhanced by 10.9 and 10.6%, respectively, as compared to control-I (Table-30).

6.1.2. Fecundity and Fertility

The normal and active adults, which emerged from the treated nymphs of each set, were allowed to mate with the females of the same age and set. Each pair was kept separately and the average fecundity of the affected females were recorded. The mean fecundity with respect to the application of the aforesaid concentrations of aminocarb also decreased linearly with increase in strength of this chemical ($Y=356.47 - 18671.87 X$, $r= - 0.9366$ $p<0.05$) and yielded a strong correlation with increasing concentrations (fig.11). However, after the topical application of 0.0006, 0.0008 and 0.001% aminocarb per 4th instar nymph, the fecundity was reduced by 1.94 ($t=1.0516$, $p>0.05$), 3.89% ($t=1.8257$, $p>0.05$) and 8.06% ($t=2.0712$, $p>0.05$), respectively, as compared to control-I (Table-11). But there was significant reductions in average egg production of the affected females with respect to 0.002 and 0.004% aminocarb/nymph, which were 16.11 ($t=3.3143$, $p<0.05$) and 19.44% ($t=4.0874$, $p<0.01$) more as compared to control-I (Table-11).

The hatchability of the eggs laid by these affected females following the aforesaid concentrations/4th instar nymph also declined linearly and showed a negative correlation with insecticide concentrations ($Y=343.83 - 33808.59 X$, $r= - 0.9175$, $p<0.05$, fig.11). The average fertility of the eggs laid by the affected females of the different sets of nymphs which were treated with 0.0006 and 0.0008% aminocarb was reduced insignificantly by 2.58 ($t=1.7660$, $p>0.05\%$) and 4.68% ($t=2.3462$, $p>0.05$), respectively, as compared to control-I (Table-11). Whereas the application of 0.001, 0.002, and 0.004% aminocarb/nymph showed statistically

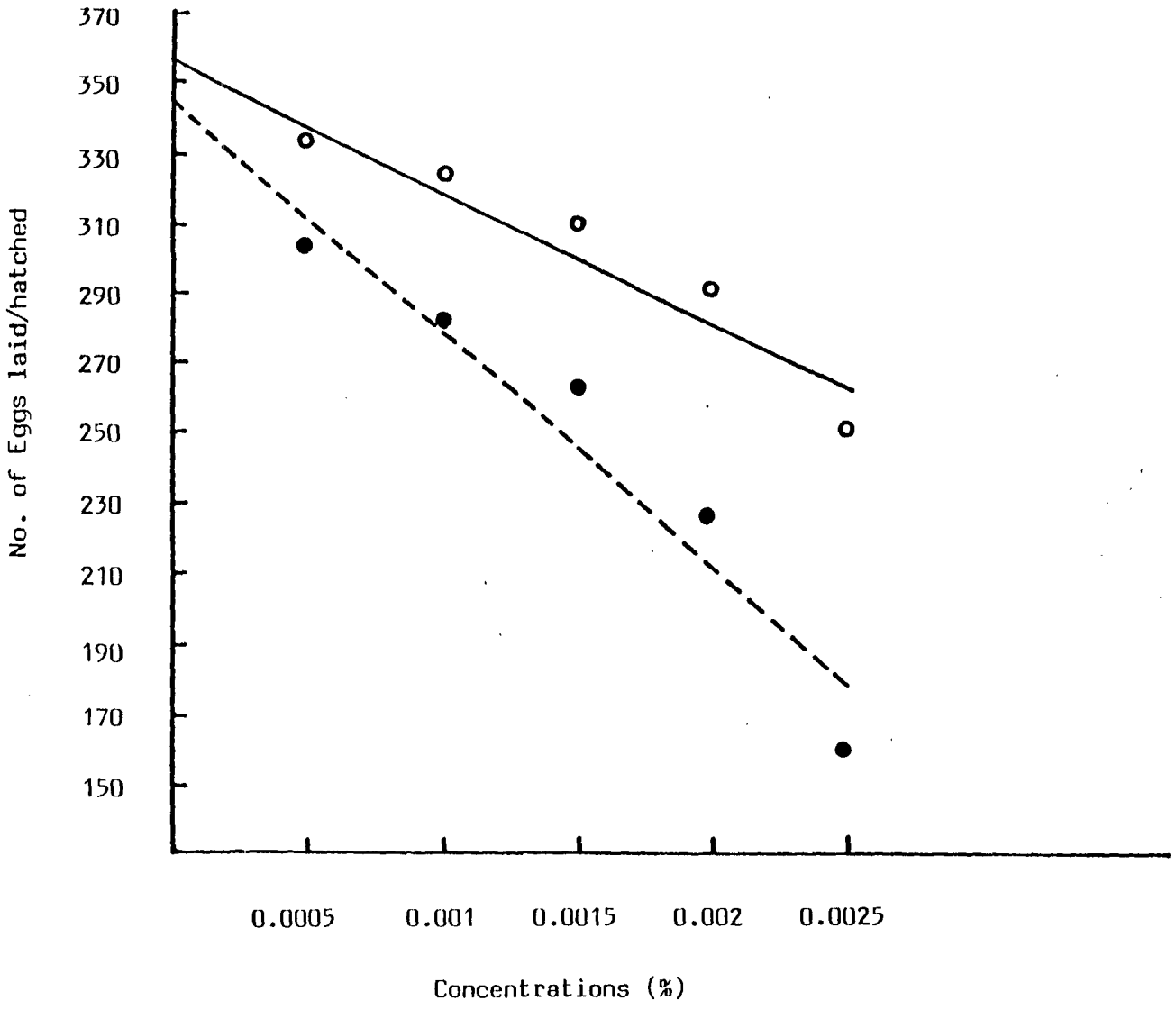

Fig. 11. Linear reduction in fecundity (o) and fertility (●) of *D. cingulatus* females emerged from 4th instar treated nymphs following topical application of different concentrations of aminocarb.

significant fall in the fertility of the eggs of the affected females, the calculations showed 10.69 (t=3.5353, p<0.02), 18.15 (t=4.4562, p<0.01) and 20.68% (t=5.2168, p<0.01), respective, as compared to control-I (Table-11).

6.2. Effects of Topical Application of Sublethal Concentrations of Aminocarb on 5th Instar Nymphs of *Dysdercus cingulatus* Fabr.

6.2.1. Mortality, Moulting and Longevity

In set first, the total nymphal mortality up to adult emergence was 6% which was 3% more as compared to control-II. In the set of nymphs topically applied with 0.0006% aminocarb, 6 nymphs died within the same instar, whereas, 3 lost their life due to incomplete nymphal-adult ecdysis resulting in 3% more nymphal loss up to adult emergence as compared to control-I (Table-12). With respect to the group of nymphs which were applied with 0.0008% aminocarb(set three), 9 nymphs died within 5th instar, whereas, 4 died during nymphal-adult moulting contributing to total loss of 13% up to adult emergence which was 7% more as compared to control-I. Out of the emerged adults, 9 were with malformed wings. In another set of 5th instar (set four), which were treated with 0.001% aminocarb, 13 nymphs died within the same instar and 5 could not moult completely and lost their lives thereby the total nymphal mortality up to adult emergence was 12% more as compared to control-I (Table-12). There were 7.7% malformed adults, out of those adults which emerged from survived nymphs. The 5th instar nymphs which were treated with 0.002% aminocarb (set five), the mortality within the same instar was 16% more, whereas, 7 nymphs died due to incomplete nymphal-adult ecdysis. The total loss up to adult emergence was 21% more as compared to control-I (Table-12). Among the emerged adults, 9.4% showed malformation in their wings. The nymphal duration of 5th instar was increased by 17.2%, however, the mean life span of adult males and females increased by 17.9 and 12.4%, respectively, as compared to control-I (Table-30). In set six, the topical application of 0.004% aminocarb/nymph resulted in 24% more deaths within the same instar, whereas, 8 nymphs could not cast off their

exuviae completely and succumbed to incomplete ecdysis. The total nymphal mortality up to adult emergence was 30% more as compared to control-II (Table-12). Further, 12.3% adults among those which emerged from the survived 5th instar nymphs showed malformation in their wings, these malformed adults were lethargic, weak and not compatible. The mean nymphal duration of 5th instar was prolonged by 23.6%, whereas, the mean life span of adult males and females was enhanced by 28 and 20%, respectively, in comparison to control-I (Table-30).

6.2.2. Fecundity and Fertility

The mean fecundity of the affected females emerged from the 5th instar nymphs following the topical application of aforesaid concentrations once again declined linearly with respect to relatively high concentrations ($Y= 352.92 - 12207.03 X$, $r= - 0.8835$, $p<0.05$, fig.12). Following the application of 0.0006, 0.0008 and 0.001% aminocarb, the average egg laying of the affected females dropped by 3.57 ($t=1.5277$, $p>0.05$), 9.89 ($t=2.5332$, $p>0.05$) and 6.87% ($t=2.1167$, $p>0.05$), respectively, as compared to control-I, which was statistically insignificant (Table-12). However, the topical application of 0.002 and 0.004% aminocarb per 5th instar nymph caused 10.99 ($t=2.6608$, $p<0.05$) and 15.11% ($t=3.3885$, $p<0.02$) significant fall in average egg deposition, respectively, as compared to control-I (Table-12).

Likewise, the mean fertility of the eggs laid by the above females also reduced linearly ($Y=349.23 - 28496.09 X$, $r= - 0.9466$, $p<0.05$ fig.12) with increase in concentrations. After the application of the lower concentrations i.e. 0.0006 and 0.0008% aminocarb, the average hatchability of the eggs declined by 1.98 ($t=1.6634$, $p>0.05$) and 4.97% ($t=2.5181$, $p>0.05$), respectively, as compared to control-I, which was statistically insignificant (Table-12). However, on the topical application of 0.001, 0.002 and 0.004% aminocarb/5th instar nymph of *D. cingulatus*, the average fertility of the eggs significantly dropped by 10.70 ($t=3.3364$, $p<0.05$), 11.86 ($t=3.9223$, $p<0.02$) and 19.94% ($t=4.5800$, $p<0.01$), respectively, as compared to control-I (Table-12).

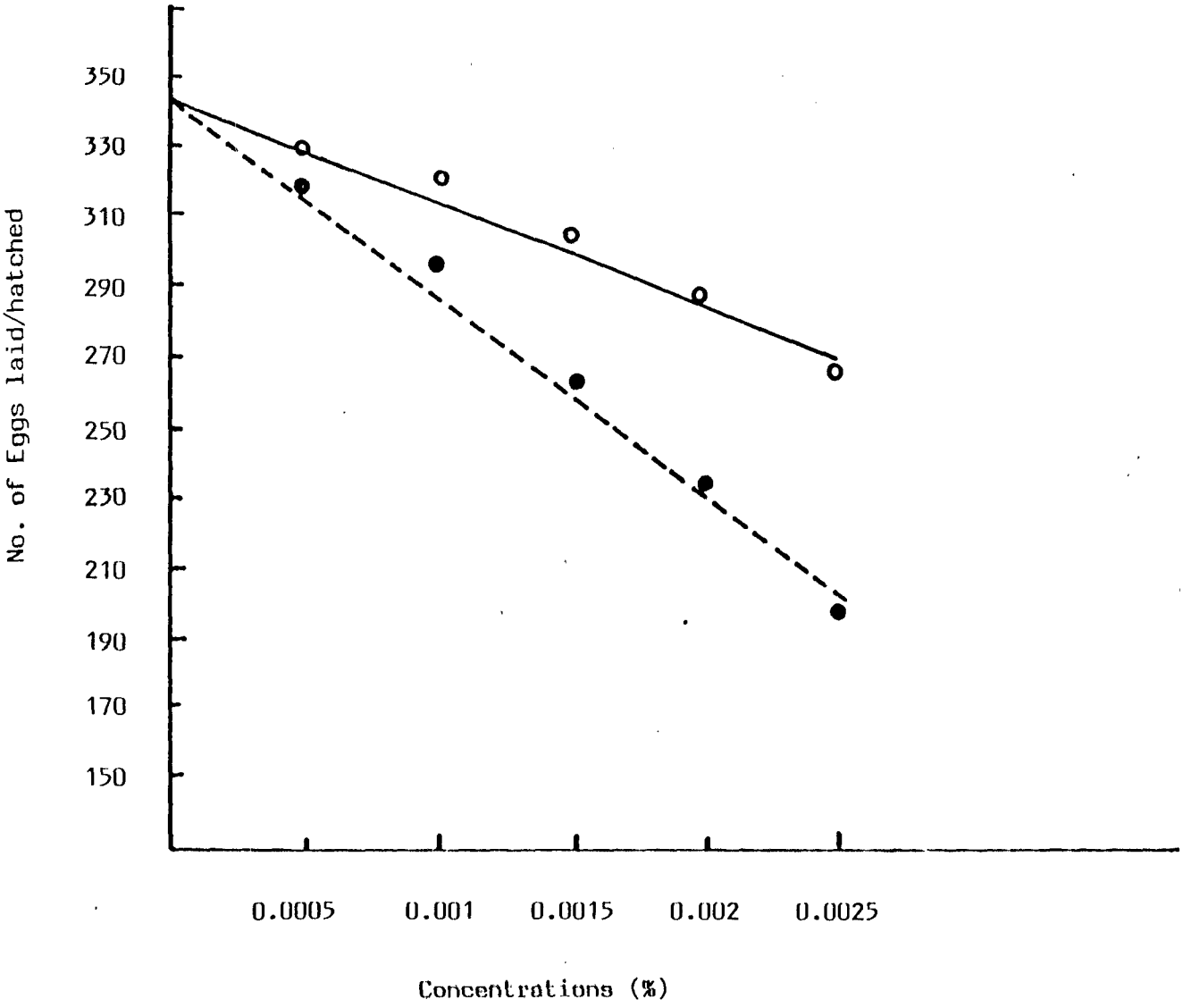

Fig. 12. Linear reduction in fecundity (o) and fertility (●) of *D. cingulatus* females emerged from 5th instar treated nymphs following topical application of different concentrations of aminocarb.

7.1. Effects of Topical Application of Sublethal Concentrations of Acephate on 5th Instar Larvae of *Diacrisia obliqua* WIK.

As mentioned in the case of *Dysdercus cingulatus*, same insecticides were also applied on the 5th and 6th instar larvae of *Diacrisia obliqua*. In this section the effect of topical application of acephate on 5th instar larvae of *D. obliqua* has been described on mortality, moulting, longevity, fecundity and fertility.

7.1.1. Mortality, Moulting and Longevity

In the first set of 100 larvae, each was topically treated with 2 µl of acetone, the total loss of larvae up to adult emergence was 1% less as compared to untreated larvae (control-II). The adults which emerged from the survived treated larvae were normal, healthy and active (Plate-XI, Fig. A). As there was no significant difference between the acetone treated (control-I) and untreated (control-II) sets, further reference of control in following text was made only to control-I. Following the topical application of 2 µl of the lowest concentration of acephate (0.02%) in second set, the mortality was insignificant both within the same instar and up to adult emergence. The total mortality up to adult emergence was 5% more as compared to control-I. The adults which emerged from the survived larvae were quite normal, healthy and active. On the topical application of 0.04% acephate (set three), 9 larvae died within the same instar, whereas, 2 lost their lives during the larval-pupal transformation. The total loss of life up to adult emergence was 9% more as compared to control-I (Table-13). The adults emerged from the treated larvae were morphologically normal, healthy and active. In set four, each of the 100 larvae was applied with 0.06% acephate, mortality of 15 larvae occurred during the same instar, whereas, 8 died during the larval-pupal ecdysis. Further, the loss of 3 individuals took place at pupal stage. Consequently there was 24% more loss in adult emergence as compared to control-I (Table-13). The emerged adults from the treated larvae were healthy, active and normal morphologically. In set five, where each larva was applied with 0.08% acephate, 24 suffered mortality within the same instar, whereas, one died at the moulting to 6th instar. Further, the death of 7

individuals occurred during the larval-pupal moulting and 8 died during the pupal stage. The total loss of larvae up to adult emergence was 38% more as compared to control I (Table-13). Out of the emerged adults from the treated larvae, 4.7% were with malformed wings and were weak and lethargic. The mean longevity of the 5th and 6th instar larvae was enhanced by 17.9 and 8.7%, respectively, than the control-I. The pupal duration was increased by 13%, whereas, the survival of adults males and females was prolonged by 12 and 8%, respectively, as compared to control-I (Table-31). In set six of 100 larvae, the topical application of the strongest sublethal concentration of acephate (0.1%) resulted in 35% mortality within the same instar, whereas, 3 larvae died during the ecdysis to 6th instar. Further, 9 larvae could not survive larval-pupal transformation (Plate-XI, Fig. D), whereas, 6 lost their lives during pupal stage. Therefore, the total loss in adult emergence after the topical application of 0.1% acephate/larva was 51% more as compared to control I (Table-13). Furthermore, the application of this concentration halted larval and pupal growth which resulted in small and light weight pupae as compared to control (Plate-XI, Fig. E). Out of the emerged adults from the treated larvae, 9.3% were with malformed wings (Plate-XI, Fig. F). These malformed adults were very weak and lethargic. The duration of 5th and 6th instar larval stage was increased by 31 and 17%, respectively, whereas, the duration of pupal stage was enhanced by 28%. The mean life span of adult males and females was increased by 14 and 13%, respectively, as compared to control-I (Table-31).

7.1.2. Fecundity and Fertility

The normal, active and healthy emerged males of each set were allowed to mate with their respective virgin females by keeping each pair separately. Then the average fecundity of the females emerged following the topical application of the aforesaid concentrations on 5th instar larvae of *Diacrisia obliqua* dropped linearly with stronger concentrations ($Y=1883.76 - 2618.57 X$, $r= - 0.9908$, $p<0.001$) and yielded a strong negative correlation (fig.13). Following the topical application of the aforesaid concentrations except 0.1%, the fall in the average egg production was insignificant. The topical application of 0.02, 0.04, 0.06 and 0.08% of acephate reduced the average egg laying of the affected females by 1.73 ($t=0.9708$, $p>0.05$),

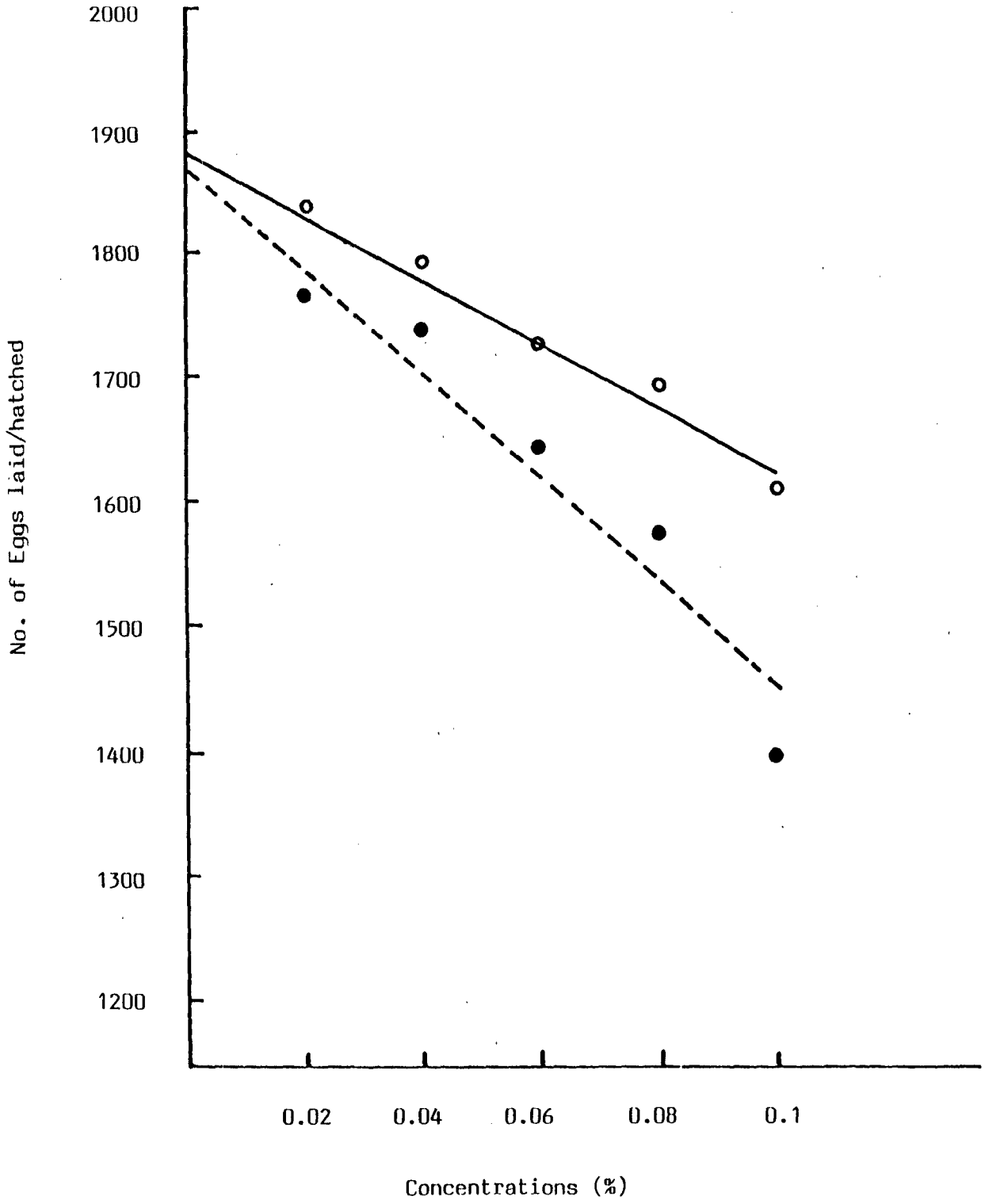

Fig.13. Linear reduction in fecundity (o) and fertility (●) of *D. obliqua* females emerged from 5th instar treated larvae following topical application of different concentrations of acephate.

4.33 (t=1.454, p>0.05), 7.81 (t=2.1330, p>0.05) and 9.52% (t=2.5300, p>0.05), respectively, as compared to control-I (Table-13). Whereas the topical application of 0.1% acephate resulted in 14.22% (t=3.1560, p<0.05) reduction in the average egg production of affected females in comparison to control-I (Table-13) which was statistically significant.

The average hatching of the eggs laid by the affected females after the topical application of the aforesaid concentrations declined linearly with respect to concentration strength (Y=1869.48 - 4202.86 X, r= - 0.9729, p<0.05) and yielded a strong correlation (Fig.13). Following the topical application of 0.02, 0.04, 0.06 and 0.08% of acephate, the fall in the average hatching of the eggs was 2.96 (t=0.6468, p>0.05), 1.95 (t=1.8103, p>0.05), 3.92 (t=2.5763, p>0.05) and 5.90% (t=2.6420, p>0.05), respectively, more as compared to control-I (Table-13). Whereas, in comparison to control-I, the topical application of 0.01% acephate per 5th instar larva showed 11.96% (t=3.6496, p<0.05) reduction in the average fertility of the eggs (Table-13).

7.2. Effects of Topical Application of Sublethal Concentrations of Acephate on 6th Instar Larvae of *Diacrisia obliqua* Wlk.

7.2.1. Mortality, Moulting and Longevity

In the first set of 100 larvae, (acetone treated) the total larval and pupal mortality up to adult emergence was 3% more as compared to control-II. The emerged adults from the survived larvae were healthy and active. The topical application of the lowest concentration, 0.02% acephate/larva (set two) did not result in significant mortality either within the present instar or up to adult emergence. However, the total mortality up to adult emergence after the application of 0.02% acephate was 1% less as compared to control-I (Table-14). The emerged adults from the treated larvae were active and healthy. In the third set, where each larva was applied with 0.04% acephate, 4 died within the same instar, whereas, mortality

of 2 larvae occurred during the larval-pupal transformation. The total loss up to adult emergence was 2% more in comparison to control-I (Table-14). The adults which emerged from the survived larvae were not as healthy as those of controls but they were normal morphologically. In the fourth set of 100 larvae which were applied with 0.06% acephate, 6 suffered mortality within the same instar, whereas, 7 larvae lost their lives during the larval-pupal transformation. The mortality of 4 occurred during the pupal stage. The total loss up to adult emergence following the application of 0.06% acephate/larva was 13% more than the control-I. The adults which emerged from the survived treated larvae were normal, but weak. In the fifth set where the each 6th instar larva was treated with 0.08% acephate, the mortality of 19 larvae occurred within the same instar and 5 died during the larval-pupal moult. Further, the mortality of 3 individuals occurred within the pupal stage and 6 pupae were abnormal morphologically. The total loss of larvae up to adult emergence following the topical application of this concentration was 23% more as compared to control-I (Table-14). Out of the adults which emerged from the survived treated larvae, 7.7% were with malformed wings. The treatment of 6th instar larvae with 0.08% acephate resulted in 9% prolongation in the average larval duration, however, the pupal duration was enhanced by 11% as compared to control-I. The average survival of adult males and females was increased by 18 and 6%, respectively, than the control-I (Table-31). In the sixth set, after the topical application of 0.1% acephate/larva, 20 larvae died within the same instar, whereas, mortality of 9 larvae occurred at larval-pupal moulting stage and 5 died during pupal stage. The total loss of larvae up to adult emergence was 30% more as compared to control-I (Table-14). Out of the total emerged adults from the survived larvae, 12.4% were with malformed wings. The mean survival of 6th instar treated larvae was enhanced by 14%, whereas, the average pupal duration was prolonged by 22% as compared to the control-I. The survival of adult males and females was 26 and 13% more than the control-I (Table-31).

7.2.2. Fecundity and Fertility

The healthy, active and morphologically normal males emerged from each set of treated larvae were allowed to mate with their respective females of the same set

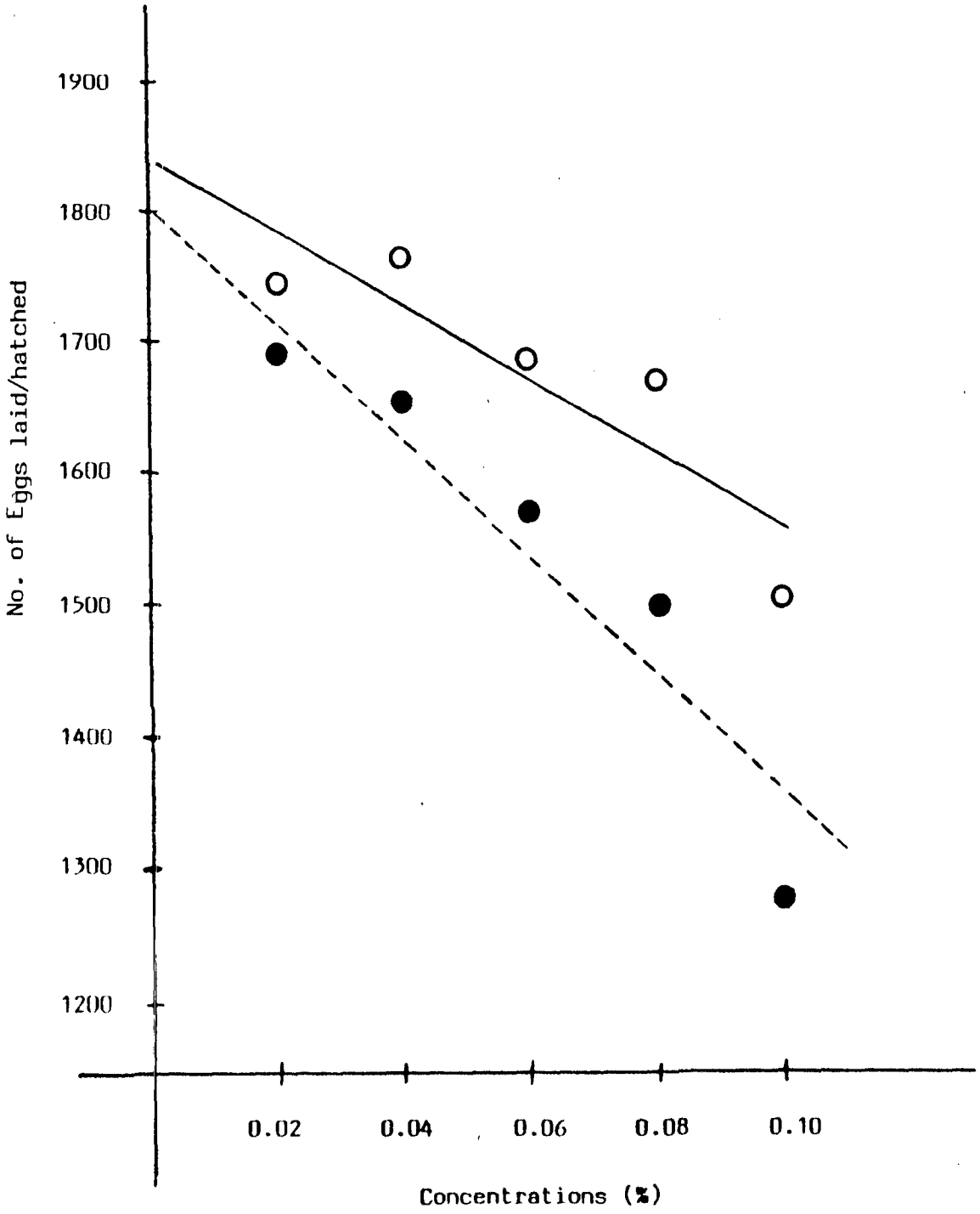

Fig.14. Linear reduction in fecundity (o) and fertility (●) of *D. obliqua* females emerged from 6th instar treated larvae following topical application of different concentrations of acephate.

and age by maintaining each pair separately. The average egg production of the affected females following the topical application of the aforesaid concentrations dropped linearly with increase in concentration strength (Y=1839.33 - 2779.99 X, r= - 0.9263, p<0.05) and yielded a negative correlation (Fig.14). With regard to the topical application of 0.02, 0.04, 0.06 and 0.08% of acephate/larva, the average fecundity of the affected females dropped by 5.01 (t=1.4947, p>0.05), 3.98 (t=1.5110, p>0.05), 8.01 (t=2.1179, p>0.05) and 9.05% (t=2.2287, p>0.05), respectively, as compared to control-I (Table-14), but such changes were statistically insignificant. On the other hand, the topical application of 0.1% acephate/larva showed significant fall of 17.98% (t=3.0023, P<0.05) in the average egg production of the affected females as compared to control-I (Table-14).

The fertility of the eggs laid by the affected females following the topical application of the aforesaid concentrations also declined linearly with increase in concentrations (Y=1805.14 - 4512.86 X, r= - 0.9593, p<0.05) and yielded negative correlation (fig.14). The hatchability of the eggs after the topical application of 0.02% acephate/larva was however enhanced slightly by 0.02% (t=1.8512, p>0.05). But the viability of the eggs of the affected females with respect to the topical application of 0.04, 0.06, 0.08 and 0.1% acephate/larva was reduced by 3.02 (t=2.3398, p>0.05), 4.05 (t=3.0528, p<0.05), 7.01 (t=3.4527, p<0.05) and 12.02% (t=4.0208, p<0.05), respectively, as compared to that of control-I (Table-14).

8.1. Effects of Topical Application of Sublethal Concentrations of Ethion on 5th Instar Larvae of *Diacrisia obliqua* Wlk.

8.1.1. Mortality, Moulting and Longevity

In the first set, each of the 100 larvae (5th instar) was applied topically with 2 µl of acetone solution only, the total larval and pupal loss up to adult emergence was 3% more as compared to that of control-II (untreated larvae). The adults which emerged from the treated larvae were healthy, active and normal morphologically

like those adults which emerged from untreated larvae (control-II). In the second set of 100 larvae, the topical application of the lowest concentrations (0.08%) of ethion/larva resulted in the mortality of 5 individuals within the same instar, whereas, 2 died at larval-pupal ecdysis and 4 within the pupal stage. The total loss of larvae upto adult emergence was 6% more as compared to that of control-I (5%). The adults which emerged from the treated larvae were normal, active and healthy. In the third set, where each of the 100 larvae was treated with 0.1% ethion, the mortality of 9 individuals occurred within the same instar, whereas, 1 died during the 6th instar. Further, the mortality of 8 individuals took place at larval-pupal ecdysis and one died during the pupal stage. The total loss in adult emergence after the topical application of 0.1% ethion/larva was 14% more as compared to that of control-I (Table-15). The adults which emerged from the treated larvae were active, normal and healthy. In the fourth set, where 100 larvae (5^{th} instar) were treated with 0.2% ethion, mortality of 16 occurred within the same instar, whereas, loss of 3 larvae occurred during 6th instar. Further the loss of 7 occurred at larval-pupal ecdysis and that of 2 at the pupal stage. Consequently, there was 23% more loss in adult emergence as compared to that of control-I (Table-15). The adults emerged from the treated larvae were healthy, active and normal. The topical application of 0.4% ethion/larva (fifth set) induced mortality of 24 larvae within the present instar, whereas, 2 died during the next instar (6th). The mortality of 9 individuals occurred during the larval-pupal transformation and 4 died in the pupal stage. The total larval and pupal loss upto adult emergence was 34% more than that of control-I (Table-15). Out of the emerged adults from the treated larvae, 6.8% were with malformed wings. These malformed adults were comparatively less active and not as healthy as unaffected adults emerged from untreated larvae. In the sixth set, the topical application of 0.6% ethion/larva caused mortality of 38 larvae within the same instar, whereas, 2 died in the next instar. Further, the mortality of 12 larvae occurred during the larval-pupal transitional stage and 5 lost their life during the pupal stage. The total larval and pupal mortality up to adult emergence was 52% more than that of control-I (Table-15). Out of the emerged adults from the treated larvae, 9.3% were with malformed wings. The average larval duration of 5^{th} and 6^{th} instar was increased by 15.9 and 17.9%, respectively, whereas, the mean pupal duration was prolonged by 14%. The longevity of adult males and females which emerged from

the treated larvae was increased by 12 and 11%, respectively, as compared to control-I(Table-32).

8.1.2. Fecundity and Fertility

The newly emerged males (one day old) of each set which were normal, active and healthy were allowed to mate with the virgin females of the same set and age by keeping each pair separately. The average fecundity of the affected females following the topical application of the aforesaid concentrations dropped linearly with increasing concentrations ($Y=1807.94 - 535.25 X$, $r= - 0.9396$, $p<0.05$) and yielded a strong negative correlation (fig.15). Following the topical application of the lowest sublethal concentration of ethion (0.08%), the egg production was increased by 0.99% ($t=1.1339$, $p>0.05$) as compared to control-I. However, with respect to the topical application of 0.1, 0.2, 0.4 and 0.6% ethion per 5th instar larva, there were 6.01 ($t=2.0885$, $p>0.05$), 8.98 ($t=2.5862$, $p<0.05$), 11.02 ($t=2.6430$, $p<0.05$) and 18.02% ($t=3.2499$, $p<0.5$) reductions in the average egg production of the affected females, respectively, in comparison to control-I (Table-15).

Similarly, the fertility of the eggs laid by the affected females following the topical application of the aforesaid concentrations also declined linearly with increasing concentrations ($Y=1671.36 - 533.44 X$, $r= - 0.7951$, $p<0.05$) with negative correlation (fig. 15). The fertility of the eggs following the topical application of 0.08 and 0.1% ethion/larva dropped insignificantly by 2.03 ($t=1.6842$, $p>0.05$) and 4.99% ($t=2.7283$, $p<0.05$), respectively, as compared to control-I. But the viability of the eggs after the topical application of 0.2, 0.4 and 0.6% ethion/larva was significantly reduced by 9.01 ($t=3.1784$, $p<0.05$), 12.13 ($t=3.8656$, $p<0.05$) and 13.28% ($t=3.4503$, $p<0.05$), respectively, as compared to that of control-I (Table-15).

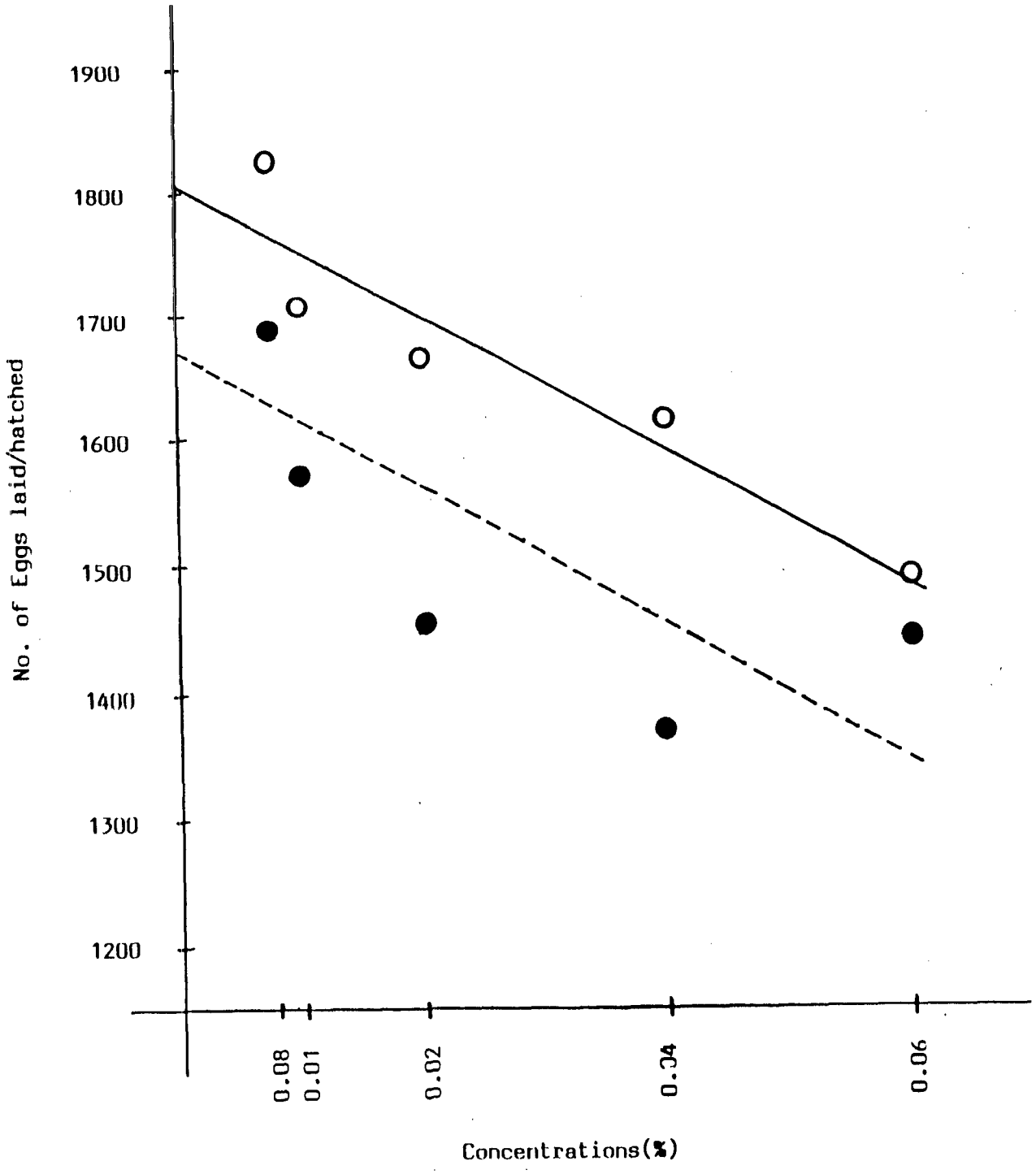

Fig.15. Linear reduction in fecundity (o) and fertility (●) of *D. obliqua* females emerged from 5th instar treated larvae following topical application of different concentrations of ethion.

8.2. Effects of Topical Application of Sublethal Concentrations of Ethion on 6th Instar Larvae of *Diacrisia obliqua* Wlk.

8.2.1. Mortality, Moulting and Longevity

In first set, each of the 100 larvae (6th instar) was individually treated with 2 µl of acetone only, then the total larval mortality up to adult emergence was 1%. The adults which emerged from the treated larvae were healthy, active and morphologically normal. In set 2, where each larva was applied with 2 µl of the lowest concentration (0.08%), 4 larvae died within the same instar, whereas, 1 death occurred during the larval-pupal transformation leading to a total larval loss up to adult emergence as 4% which was 3% more as compared to control I. The emerged adults from the treated larvae were active, healthy and normal morphologically. In the third set of this experiment, the topical application of 0.1% ethion per 6th instar larva resulted in 6% mortality within the same instar, whereas, 3 larvae died during the larval-pupal ecdysis. Further, 1 mortality in pupal stage resulted in total loss of 9% in adult emergence as compared to control-I (Table-16). The adults which emerged from the treated larvae were normal morphologically, active and healthy. In the set 4, the topical application was made with 0.2% ethion. Thereafter, 9 larvae died within the present instar, whereas, 4 larvae could not completely transform into pupal stage and died. The mortality of 5 individuals occurred during the pupal stage leading to a total larval loss up to adult emergence as 18% which was 17% more as compared to control-I (Table-16). When the adults emerged from the treated larvae, 5.3% were with malformed wings. These adults were comparatively weak and lethargic. In fifth set, each larva was applied with 0.4% ethion. Thereafter, 23 larvae died during the same instar, further, 4 and then 3 larvae died during larval-pupal transformation and the pupal stage, respectively. The total loss of larvae and pupae up to adult emergence was 29% more as compared control-I (Table-16). Out of the total emerged adults from the treated larvae, 8.2% were with malformed wings which were weak and lethargic. In the sixth set, after the topical application of the highest sublethal concentration of ethion (0.6%) the mortality was 29 within the same instar, 8 during the larval-pupal transformation and 4 in pupal stage. The total death toll of

larvae up to adult emergence was 40% more as compared to control-I (Table-16). Out of the emerged adults, from the treated larvae, 13.3% had malformed wings and these were weak and lethargic as well. The duration of larval instars was enhanced by two days, whereas, the duration of the pupal stage was increased by 4 days as compared to control- I. The average survival of 6^{th} instar larvae following the application of the highest selected concentration was increased by 13% than the control-I, whereas, the average pupal stage of the survived treated larvae was prolonged by 18%. The average life span of adult males and females which emerged from such pupae enhanced by 14 and 9%, respectively, as compared to control-I (Table-32).

8.2.2. Fecundity and Fertility

The emerged males which were active, healthy and morphologically normal were allowed to mate with their respective virgin females of the same set and age by keeping each pair separately. As regard the average egg production of these affected females following the topical application of the aforesaid concentrations of ethion, there was linear fall with increase in concentration strength (Y=1755.2 - 405.41 X, r= -0.9585, $p<0.01\%$) and yielded negative correlation (fig.16). The average egg laying of the affected females after the topical application of the lower concentrations (i.e. 0.08 and 0.1%) dropped by 6.05 ($t=2.0389$, $p>0.05$) and 05.05% ($t=1.9344$, $p>0.05$), respectively, as compared to control-I (Table-16). Whereas following the topical application of the higher sublethal concentrations (0.2, 0.4 and 0.6%) there was 8.05 ($t=2.6467$, $p<0.05$), 12.05 ($t=2.6436$, $p<0.05$) and 15.11% ($t=3.4188$, $p<0.05$) significant reductions in the average egg production of the affected females, respectively, as compared to control-I (Table-16).

Similarly, the fertility of the eggs laid by the affected females following the topical application of the aforesaid concentrations also dropped linearly with increasing concentrations (Y=1713.0 - 804.4 X, r= - 0.9683, $p<0.05$) and in this case also yielded a negative correlation (fig.16). The average hatchability of the eggs laid by the affected females following the topical application of 0.08, and 0.1% ethion/larva dropped by 4.09 ($t=2.6694$, $p<0.05$) and 02.87% ($t=2.3095$, $p>0.05$),

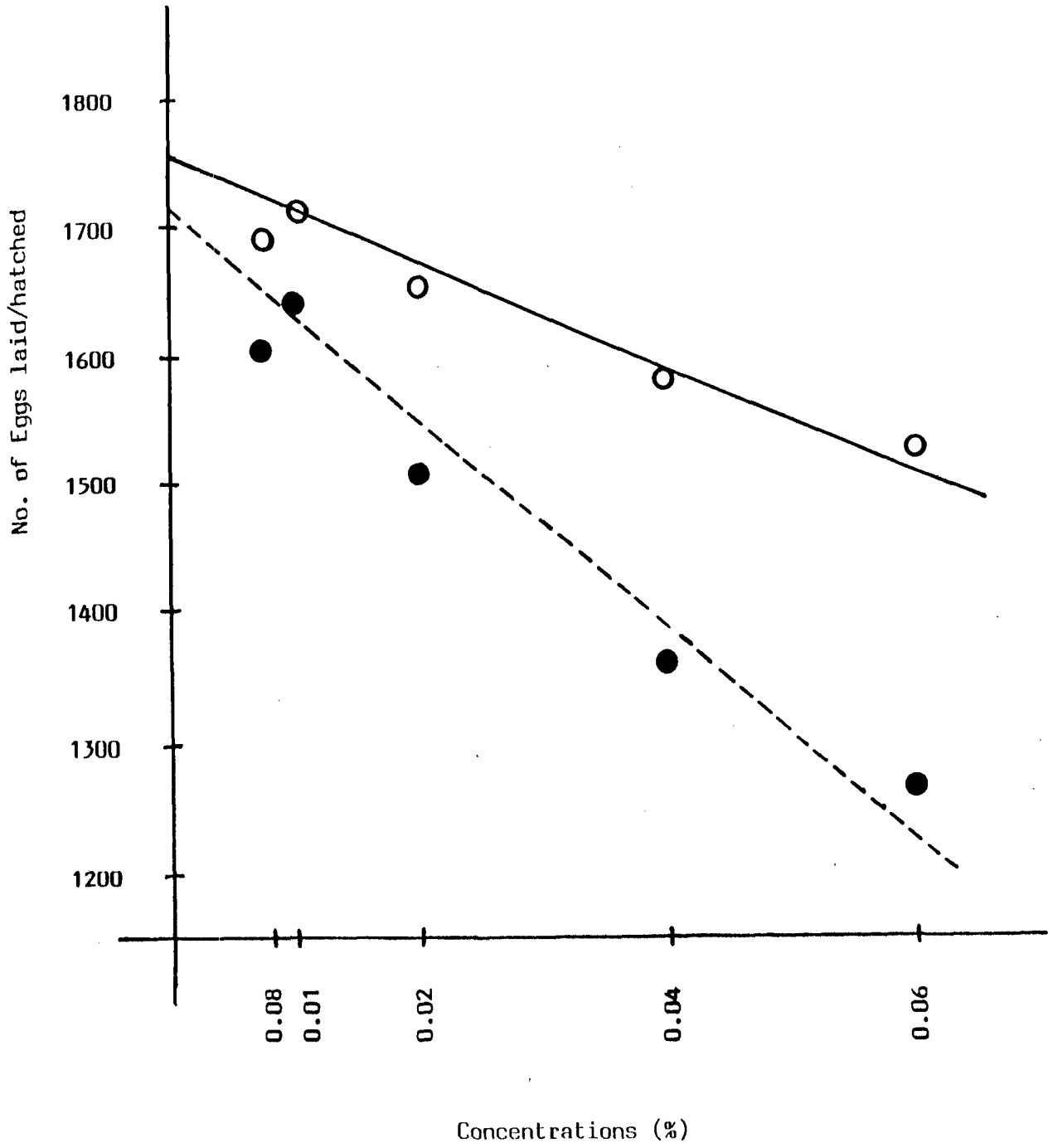

Fig.16. Linear reduction in fecundity (o) and fertility (●) of *D. obliqua* females emerged from 6th instar treated larvae following topical application of different concentrations of ethion.

respectively, as compared to control-I (Table-16). Whereas the topical application of 0.2, 0.4 and 0.6% ethion resulted in the 7.95 ($t=3.1985$, $p<0.05$), 12.97 ($t=4.1429$, $p<0.05$) and 15.96% ($t=4.7299$, $p<0.05$) reduction in the average fertility of the eggs, respectively, as compared to control-I (Table-16).

9.1. Effects of Topical Application of Sublethal Concentrations of Dichlorvos on 5th Instar Larvae of *Diacrisia obliqua* Wlk.

9.1.1. Mortality, Moulting and Longevity

In the first set of this experiment, out of the 100 acetone treated larvae, the total mortality upto adult emergence was 4% which was 1% less as compared to control-II. The adults from the treated larvae were active, healthy and normal morphologically. As there was no significant difference between the acetone treated (control-I) and untreated (control-II) set, further reference of control was made only to control-I. In the second set of experimental insects, the topical application of lowest sublethal concentration of dichlorvos (0.06%) subsequently caused the death of 7 larvae within the same instar, whereas, 2 larvae lost their lives during the larval-pupal transformation. The total larval mortality upto adult emergence was 5% more as compared to control-I (Table-17). The adults which emerged from the treated larvae were active, healthy and normal. In the third set of this experiment, the topical application of 0.08% dichlorvos caused mortality of 14 within the same stage, whereas, 5 larvae died during 6th instar. The total larval and pupal mortality up to adult emergence after the topical application of this concentration was 16% more as compared to control-I (Table-17). Out of the adults which emerged from the treated larvae, 3.4% of them were weak and lethargic with malformed wings. In set 4 of 100 larvae treated with 0.1% dichlorvos, mortality of 26 larvae occurred within the same instar, 4 in the 6th instar, 3 during larval-pupal transformation and 1 within the pupal stage. Thus up to emergence of adults there was 30% loss as compared to control-I (Table-17). Out of the total emerged adults from the treated larvae, 5.1% were with malformed wings and were weak and lethargic. In another set of 100

larvae, individually treated with 2 µl 0.2% dichlorvos, 32 larvae suffered mortality within the same instar, whereas, 2 died during the 6th instar. Further, 5 larvae during the larval-pupal transformation and 7 within the pupal stage could not survive. Therefore, total larval and pupal loss after the topical application of the present strength of dichlorvos was 42% more as compared to control-I (Table-17). Among the adults emerged from the survived treated larvae, 7.6% were with malformed wings. These malformed adults were very weak and lethargic. The prolongation in mean longevity of 5th and 6th instar larvae was 13 and 8% more as compared to the control-I. The average pupal duration of 5th instar treated larvae was increased by 15%, whereas, the emerged adult males and females from such affected pupae lived 9 and 8% more than that of control (Table-33). In the set treated with the strongest sublethal concentration of dichlorvos (0.4%/larva), the death of 41 larvae occurred within the same instar, 3 in the 6th instar, 7 at larval- pupal transformation and 4 within pupal stage. The total loss of lives up to adult emergence was 51% more as compared to control-I (Table-17). Out of the total emerged adults from the survived larvae, 8.7% were with malformed wings. These malformed adults were very weak and lethargic and died after a few days. The average survival of 5th and 6th instar larvae was enhanced by 20 and 10.9%, respectively, as compared to control-I. The average pupal duration was increased by 23%, whereas, the average life span of adult males and females emerged from the affected pupae was prolonged by 16 and 9%, respectively, than control-I (Table-33).

9.1.2. Fecundity and Fertility

The emerged males of each set, which were active, healthy and normal were allowed to mate with the virgin females of the same set and age by keeping each pair separately. The average egg production of the affected females following topical application of the aforesaid concentrations declined linearly with increase in concentration strength ($Y=1755 - 1054 X$, $r= - 0.9763$, $p<0.05$) and yielded negative correlation (fig.17). The topical application of the lower concentrations (0.06 and 0.08%) of dichlorvos showed 2.94 ($t=1.4123$, $p>0.05$) and 4.97% ($t=2.6828$, $p>0.05$), reduction in the average egg production of the affected females, respectively, which were statistically insignificant. Whereas 0.1, 0.2 and 0.4%

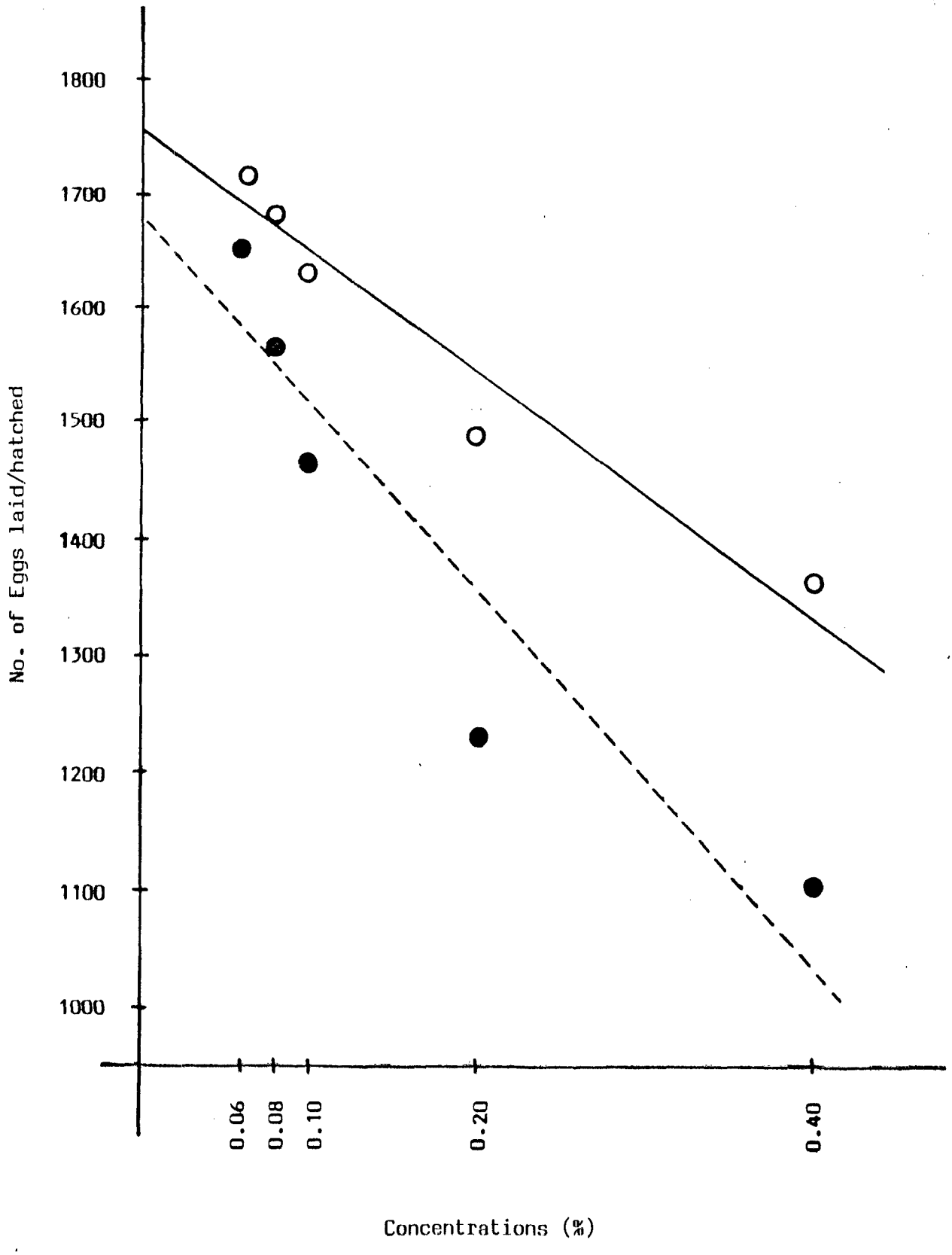

Fig.17. Linear reduction in fecundity (o) and fertility (●) of *D. obliqua* females emerged from 5th instar treated larvae following topical application of different concentrations of dichlorvos.

dichlorvos/5th instar larvae resulted in 8.02 (t=2.6828, P<0.05), 15.99 (t=3.3288, p<0.05) and 23.05% (t=4.2405, p<0.05) significant decrease in the average oviposition of the affected females, respectively, as compared to control-I (Table-17).

Similarly, the fertility of the eggs laid by the affected females declined linearly with increasing concentrations (Y=1679.61 - 1599.61 X, r= - 0.9492, p<0.05) and yielded negative correlation (fig.17). The topical application of the lowest sublethal concentration (0.06%) showed insignificant reduction in the average hatching of the eggs laid by the affected females which was 1.08% (t=2.1195, p>0.05) less as compared to control-I (Table-17). Whereas the topical application of 0.08, 0.1, 0.2 and 0.4% dichlorvos per 5th instar larva resulted in 4.08 (t=2.8439, p<0.05), 7.07 (t=3.6606, p<0.05), 14.07 (t=4.3315, p<0.05) and 16.0% (t=4.1235, p<0.05) significant drops in the average viability of eggs laid by the affected females, respectively, as compared to control-I (Table-17).

9.2. Effects of Topical Application of Sublethal Concentrations of Dichlorvos on 6th Instar Larvae of *Diacrisia obliqua* Wlk.

9.2.1. Mortality, Moulting and Longevity

In control-I larval, mortality up to adult emergence was 2% less as compared to control-II. All the adults which emerged from the treated larvae were active, healthy and normal. As there was no significant difference between the control-I and control-II, later reference with respect to control in this section means control-I. In second set, the topical application of the lowest sublethal concentration of dichlorvos (0.06%) did not result in significant loss either at the larval stage or up to adult emergence. The total larval and pupal loss upto adult emergence was 6% more as compared to control-I (Table-18). The adults which emerged from the survived larvae were active, healthy and normal morphologically. In the third set, when each of the 100 larvae was applied individually with 0.08% dichlorvos, then 9 larvae died within the present 6th instar, whereas, death occurred to 4 during the

pupal stage leading to 12% more loss up to adult emergence, as compared to control-I. The adults emerged from the survived larvae were healthy, active and normal. In another set (fourth) of this experiment, 100 larvae of 6th instar were treated with 0.1% dichlorvos, 15 larvae suffered mortality within the present stage, whereas, 7 and 1 larvae died during the larval-pupal transformation and pupal stage, respectively. The total loss in adult emergence after the application of 0.1% dichlorvos was 22% more as compared to control-I (Table-18). The emerged adults from the survived larvae were normal, active and healthy. In the fifth set, which was treated with 0.2% dichlorvos, mortality of 21 larvae occurred within the same instar, whereas, 4 died during the larval-pupal transitional stage and 6 individuals lost their life at pupal stage. The total loss in adult emergence after the topical application of 0.2% dichlorvos was 30% more as compared to control. Among the adults which emerged from the survived treated larvae, 4.2% were with malformed wings. In the sixth set, the topical application of 0.4% dichlorvos per 6^{th} instar larva resulted in the mortality of 28 within the same instar, whereas, 6 died during the larval-pupal transformation. Further, 3 mortalities occurred at pupal stage. Consequently there was 36% more loss in adult emergence as compared to control-I (Table-18). Out of the emerged adults from the treated larvae, 6.2% were with malformed wings. These malformed adults were very lethargic and weak. The survival duration of 6^{th} instar larvae was 11% more as compared to control, whereas, 9% increase in the pupal duration was observed. The average duration of adult stage of males and females was enhanced by 16 and 12%, respectively, as compared to control-I (Table-33).

9.2.2. Fecundity and Fertility

The emerged males from each set, which were active, healthy and normal, were allowed to mate with the virgin females of their respective sets and each pair was kept separately. The average egg production by the females following the topical applications of the aforesaid concentrations reduced linearly with increasing concentrations ($Y=1701.16 - 776.17\ X$, $r= - 0.9534$, $p<0.05$) and yielded negative correlation (fig.18). The topical application of the lowest sublethal concentration of dichlorvos developed insignificant reduction in the average egg oviposition of the

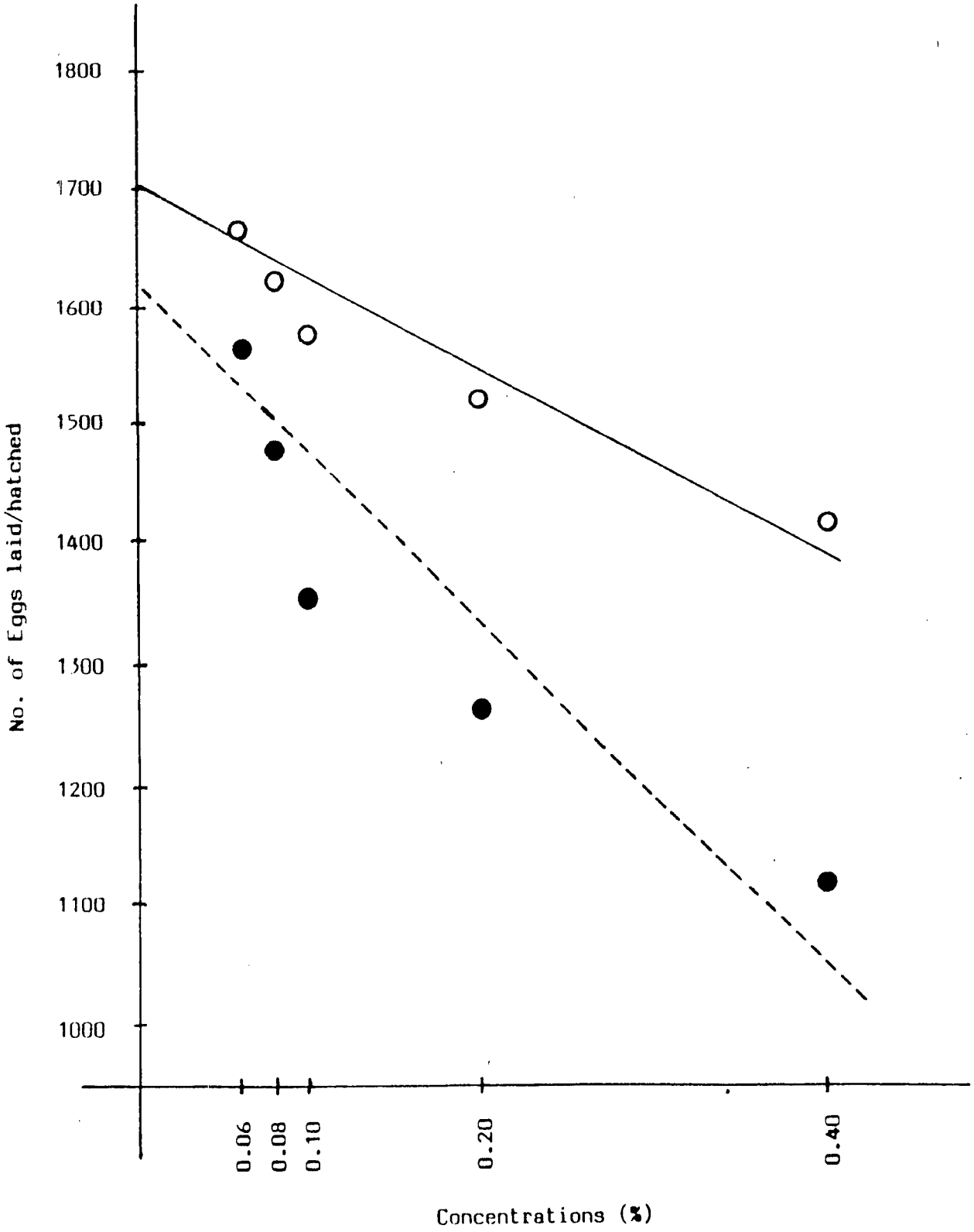

Fig.18. Linear reduction in fecundity (o) and fertility (●) of *D. obliqua* females emerged from 6th instar treated larvae following topical application of different concentrations of dichlorvos.

females, which was 4.97% (t=2.0153, p>0.05) less as compared to control-I (Table-18). Whereas the topical application of 0.08, 0.1, 0.2 and 0.4% dichlorvos/6th instar larva resulted in significant loss in the average egg laying of the females, which were 07.14 (t=2.5649, p<0.05) 9.94 (t=2.8964, p<0.05), 13.14 (t=3.4683, p<0.05) and 19.13% (t=4.3802, p<0.05) less, respectively, as compared to control-I (Table-18).

Similarly, the hatching of the eggs laid by the affected females after the topical application of the aforesaid concentrations also reduced linearly with increasing concentrations (Y=1621.05 - 1426.56 X, r= - 0.9113, p<0.05) and yielded a negative correlation (fig.18). Following the topical application of 0.06 and 0.08% dichlorvos/6th instar larva, the average viability of the eggs decreased by 5.78 (t=2.5447, p<0.05) and 08.75% (t=2.8189, p<0.05), respectively, as compared to control I (Table). Similarly, the topical application of 0.1%, 0.2 and 0.4% dichlorvos/6th instar larva also showed 13.78 (t=3.7429, p<0.05), 16.80 (t=3.8647, p<0.05) and 20.74% (t=4.3802, p<0.05) reduction in the average viability of the eggs laid by the affected females, respectively, as compared to control-I (Table-18).

10.1. Effects of Topical Application of Sublethal Concentrations of Furadan on 5th Instar Larvae of *Diacrisia obliqua* Wlk.

10.1.1. Mortality, Moulting and Longevity

In the first set (control-I) of 100 larvae of 5th instar (one day old) which were individually applied with 2 µl acetone only, death of 2 larvae occurred within the same instar, whereas, 3 died during the ensuing stage (6th instar) leading to a total larval and pupal loss of 5% upto adult emergence which was 2% more as compared to untreated larvae (control-II). As the difference between solvent treated (control-I) and untreated (control-II) was insignificant, therefore, in the present text reference has been made only to control I for comparison. The adults which emerged from the solvent treated larvae were healthy, active and normal morphologically. In the second set of 100 larvae which were topically treated with 2 µl 0.01% furadan, there

was no significant mortality either at the larval stage or up to adult emergence. The total larval and pupal loss up to adult emergence was only 4% which was 1% less as compared to control-I (Table-19). In the third set of 100 larvae, each topically applied with 0.02% furadan, 8 larvae died within the same instar, whereas, death of one took place during the 6th instar and 3 individuals at pupal stage. Consequently, there was 7% more loss up to adult emergence as compared to control I. Among the adults which emerged from the survived treated larvae, 2.8% were with malformed wings, whereas, rest of the adults were healthy, active and normal morphologically. Further, there was no change in the longevity of either 5th or 6th instar. In the fourth set of this experiment where 0.04% furadan was applied topically on each 100 larvae, 21 larvae died within the same instar, whereas, 5 could not enter successfully into the pupal stage and succumbed to death during larval-pupal transformation. Further, the loss of 2 individuals took place at pupal stage. It resulted in a total larval and pupal loss of 25% more as compared to control-I (Table-19). Out of the total emerged adults from the treated larvae, 5.3% were with malformed wings. These malformed adults were weak, lethargic and less compatible as compared to rest of the adults. In the fifth set, each of 100 larvae was applied with 0.06% furadan, subsequently, 30 larvae died in the same stage, whereas, mortality of 2 occurred during the next (6th) instar. Further, the loss of 9 larvae occurred at the larval-pupal moulting, whereas, 4 individuals died in the pupal stage. Thus, total loss of life up to the adult emergence was 40% more as compared to control-I. Out of the adults emerged from the treated larvae, 8.4% were with malformed wings. These malformed adults were very weak, lethargic and died within a few days. In the sixth set, where the topical application was made with the strongest sublethal concentration, death was recorded for 38 larvae at the same stage, 4 in the next (6th) instar, 13 at larval-pupal transformation and 6 during the pupal stage. The total loss of lives up to adult emergence was 58% more as compared to control-I (Table-19). Out of the total emerged adults, 13.6% were with malformed wings and these malformed adults were very weak and lethargic. The average longevity of 5th and 6th instar larvae which survived the treatment was increased by 9 and 14%, respectively, as compared to control. However, the average pupal duration as well as the average life span of adult males and females

was enhanced by 25, 18, and 10%, respectively, than that of control-I (260.1, 412.4, and 213.6 hrs. respectively, (Table-34).

10.1.2.Fecundity and Fertility

The active and healthy males of each set which were also morphologically normal were allowed to mate with virgin females of their respective sets and age by keeping each pair separately. Then the average egg laying of the affected females emerged following the application of furadan on these larvae declined linearly with increase in concentration strength ($Y=1671.97 -8151.58 X$, $r= - 0.9961$, $p<0.05$) and yielded a strong negative correlation (fig.19). Following the topical application of the lower concentrations (i.e. 0.01 and 0.02%) the average egg laying of the females was insignificantly reduced by 6.98 ($t=1.6274$, $p>0.05$) and 13.21% ($t=2.0712$, $p>0.05$), respectively, as compared to control-I (Table-19). Whereas the topical application of 0.04, 0.06 and 0.08% furadan/5th instar larva resulted in 21.99 ($t=2.6524$, $p<0.05$) 31.03 ($t=3.311$, $p<0.05$) and 39.01% ($t=3.6092$, $p<0.05$) more reduction in the average egg production of the affected females, respectively, as compared to control-I (Table-19) which were statistically significant.

The hatchability of the eggs laid by the affected females following the application of different concentrations of furadan also reduced linearly with increase in concentration strength ($Y=1587.4 - 13121.05 X$, $r= - 0.9837$, $p<0.05$) and once again yielded a strong negative correlation (fig.19). The average hatchability of the eggs following the topical application of 0.01 and 0.02% furadan was dropped by 4.0 ($t=2.3935$, $p>0.05$) and 16.02% ($t=3.5556$, $p<0.05$), respectively, as compared to control-I (Table-19). However, the topical application of 0.04, 0.06 and 0.08% furadan showed 22.97 ($t=4.6489$, $p<0.05$), 29.98 ($t=5.1344$, $p<0.05$) and 40.95% ($t=5.8724$, $p<0.05$) loss in the average fertility of the eggs, respectively, as compared to control-I (Table-19).

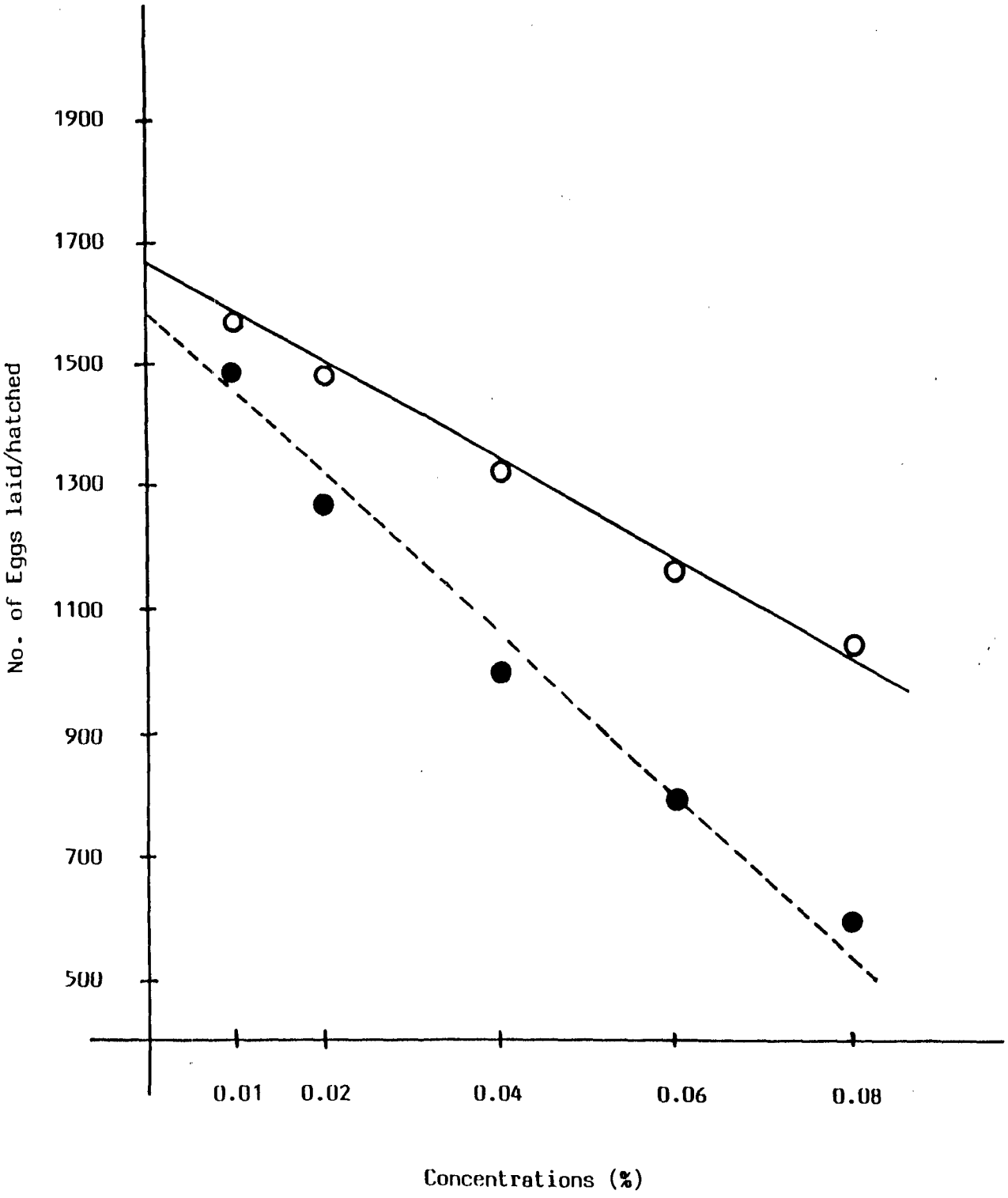

Fig.19. Linear reduction in fecundity (o) and fertility (●) of *D. obliqua* females emerged from 5th instar treated larvae following topical application of different concentrations of furadan.

10.2. Effects of Topical Application of Sublethal Concentrations of Furadan on 6th Instar Larvae of *Diacrisia obliqua* Wlk.

10.2.1. Mortality, Moulting and Longevity

Among the 100 larvae of set one (control-I) which were topically applied with 2 µl acetone (solvent), total death up to adult emergence was 2%, which was 1% more as compared to untreated (control-II). The adults which emerged from the survived larvae were active and healthy like the normal untreated larvae. In the second set of 100 larvae topically treated with 0.01% furadan, 4 larvae died within the same instar, whereas, 5 could not survive at the larval-pupal transformation. Further, death of 2 individuals occurred during the pupal stage. The total death was 9% more up to adult emergence as compared to control-I (Table-20). In the third set, where the topical application was made with 0.02% furadan/larva, mortality of 5 larvae occurred in the same stage, whereas, 4 larvae lost their lives at larval-pupal transformation. Thereby total larval and pupal loss up to adult emergence was 9%, which was 2% less as compared to that of lowest selected sublethal concentration (0.01%), whereas, it was 7% more as compared to control-I (Table-20). In the fourth set, where each of 100 larvae was applied with 0.04% furadan, 13 larvae died within the present stage, whereas, 3 could not survive at both larval-pupal transformation and pupal stage, respectively. The total loss in adult emergence following the topical application of this concentration was 17% more as compared to control-I (Table-20). Among the adults which emerged from the treated larvae, 7.2% were with malformed wings. These malformed adults were weak and lethargic. In the fifth set, each of the larvae was applied with 0.06% furadan, then the mortality was 2 within the 6th instar, 7 at larval-pupal transformation and 8 individuals died in the pupal stage giving 34% more loss in adult emergence as compared to control-I (Table-20). Out of the emerged adults from the treated larvae, 9.3% were with malformed wings. In the sixth set, the topical application of 0.08% furadan resulted in mortality of 22 larvae within the present (6th) instar, 10 larvae at larval pupal transformation and 8 individuals in the pupal stage. Thus, there was 44% more larval-pupal loss up to adult emergence as compared to control-I (Table-20). Out of

the emerged adults from the treated larvae, 13.7% were with malformed wings which were very weak, small in size and lethargic. The longevity of 6th instar treated larvae as well as adult males and females remain almost unchanged, whereas, the average pupal duration of the affected larvae was enhanced by 42 hrs as compared to control-I (Table-34).

10.2.2. Fecundity and Fertility

The morphologically normal, healthy and active males of each set were allowed to mate with their respective virgin females of the same set and age, and each pair was kept separately. The average egg production of the females following the topical application of the aforesaid concentrations of furadan dropped linearly with increasing concentration strength ($Y=1695.17 - 6990.53 X$, $r= - 0.9981$, $p<0.05$) and yielded a negative correlation (fig.20). Following the topical application of 0.01 and 0.02% furadan/larva, the average fecundity of the females was reduced by 6.01 ($t=1.6134$, $p>0.05$) and 9.0% ($t=2.1785$, $p>0.05$), respectively, as compared to control-I (Table-20). Whereas the topical application of 0.04, 0.06 and 0.08% furadan/larva resulted in 17.98 ($t=2.8099$, $p<0.05$), 25.90 ($t=3.333$, $p<0.05$) and 33.0% ($t=4.0109$, $p<0.05$) fall in the average egg production of the females, respectively, as compared to control-I (Table-20).

Similarly, the fertility of the eggs laid by the affected females following the topical application of the aforesaid concentrations also reduced linearly ($Y=1645.03 -12529.47 X$, $r= - 0.9933$, $p<0.05$) and yielded a strong correlation (fig.20). The hatchability of eggs, after the topical application of 0.01 and 0.02% furadan, reduced by 5.91 ($t=2.3735$, $p>0.05$) and 8.9% ($t=2.8534$, $p<0.05$), respectively, as compared to control-I (Table-20). Whereas the viability of the eggs following the topical application of 0.04, 0.06 and 0.08% concentrations dropped by 21.88 ($t=4.5563$, $p<0.05$), 29.89 ($t=5.4103$, $p<0.05$) and 38.96% ($t=5.9496$, $p<0.05$), respectively, as compared to control-I (Table-20).

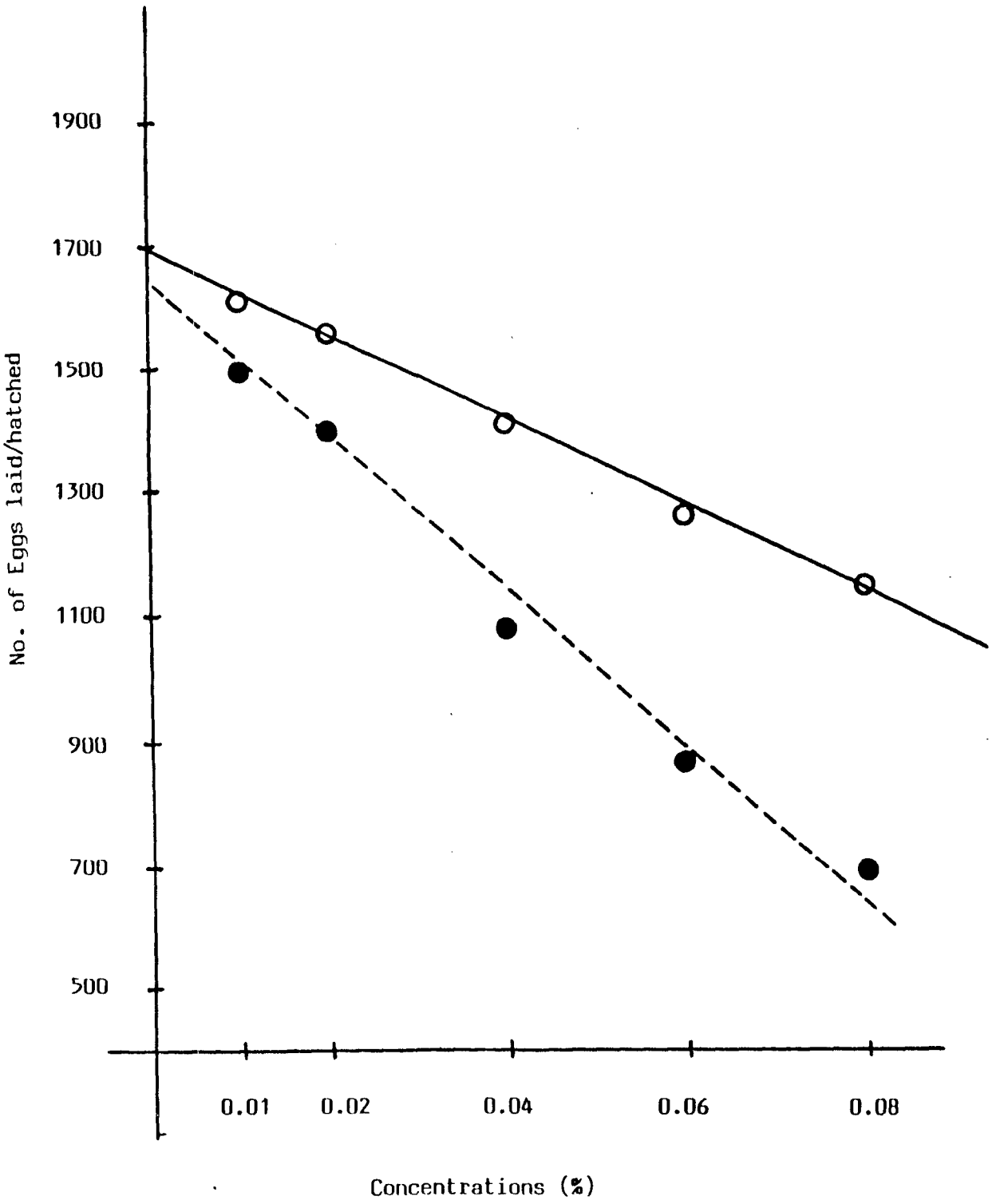

Fig.20. Linear reduction in fecundity (o) and fertility (●) of *D. obliqua* females emerged from 6th instar treated larvae following topical application of different concentrations of furadan.

11.1. Effects of Topical Application of Sublethal Concentrations of Carbaryl on 5th Instar Larvae of *Diacrisia obliqua* Wlk.

11.1.1. Mortality, Moulting and Longevity

In the first set, (control-I) 100 larvae of 5th instar (one day old) were treated individually with 2 µl of acetone (solvent) only. The total mortality upto adult emergence was 3%, which was 2% more as compared to untreated larvae (control-II). As the difference in mortality between control-I and control-II was statistically insignificant, further reference was made to control-I for comparison. The adults which emerged from solvent treated larvae were healthy active and normal morphologically. In the second set, following the topical application of the lowest sublethal concentration of carbaryl (0.04%) there was no significant mortality either within the same stage, or later up to adult emergence. The total loss of life upto adult emergence following the topical application of this concentration of carbaryl was 3% more as compared to control-I (Table-21). The adults which emerged from the treated larvae were quite healthy, active and normal morphologically. In the third set where the topical application was made with 0.06% carbaryl, 10 larvae died within the same instar, whereas, death of 1 larva each took place in 6th instar and larval-pupal transformation, respectively. Further, the mortality of 3 individuals occurred in pupal stage. Thus, there was a total loss of 15% individuals upto adult emergence which was 12% more as compared to control-I. The emerged adults were quite healthy, active and normal morphologically. In set fourth of this experiment, each of the 100 larvae of 5th instar (one day old) was treated with 2 µl of 0.08% carbaryl, 21 larvae died within the same instar, whereas, 5 each lost their life at larval pupal transformation and pupal stage, respectively. The total loss of larvae upto adult emergence was 28% more as compared to control-I (Table-21). Out of the emerged adults from the treated larvae, 3.9% adults were with malformed wings, which were comparatively weak and lethargic. In the fifth set where each of the 100 larvae was applied with 0.1% carbaryl, there was mortality of 29 larvae within the same instar, 1 in the 6th instar, 13 larvae at larval-pupal transformation and 6 in pupal stage. It, therefore, resulted in 46% more loss in adult emergence as

compared to control-I. Out of the emerged adults from the survived larvae, 8.4% adults had malformed wings. In the sixth set, the topical application of 0.15% carbaryl resulted in the mortality of 42 larvae in the present stage, 10 larvae at larval-pupal ecdysis and 7 in pupal stage. The total loss in adult emergence following the topical application of highest sublethal concentration was 56% more as compared to control-I (Table-21). Among the adults which emerged from the treated larvae, 11.3% developed with malformed wings. These adults were weak, lethargic and less active as compared to rest of the adults. The longevity of 5^{th} and 6^{th} instar larvae which survived the treatment was 22 and 15% more, respectively, as compared to control-I (97.1 hrs.). However, the pupal duration as well as adult life span of males and females of the treated larvae was increased by 20, 14, and 11% respectively, than control-I (Table-35).

11.1.2. Fecundity and Fertility

The active, healthy and morphologically normal males of each set were allowed to mate with the virgin females of their respective sets by keeping each pair separately. The average fecundity of the affected females following the topical application of different sub-lethal concentrations reduced linearly with the increase in concentration strength ($Y=1623.66 - 2434.76 X$, $r= - 0.9803$, $p<0.05$) and yielded a negative correlation (fig.21). Following the topical application of 0.04 and 0.06% of carbaryl/5^{th} instar larva, the fall in the average egg production was 4.98 ($t=1.4545$, $p>0.05$) and 8.0% ($t=1.7791$, $p>0.05$) more, respectively, as compared to control-I (Table-21). However the topical application of 0.08, 0.10 and 0.15% of carbaryl resulted in 13.97 ($t=2.3251$, $p>0.05$), 16.98 ($t=2.5892$, $p>0.05$) and 20.98% ($t=2.9483$) more reduction, in the average egg production of the affected females, respectively, as compared to control-I (Table-21).

In this case also, the fertility of the eggs laid by the affected females following the topical application of the aforesaid concentrations of carbaryl also dropped linearly ($Y=1615.82 - 5364.87 X$, $r= - 0.9707$, $p<0.05$, Fig.21) and yielded a strong negative correlation with increasing concentration strengths. The topical application of the lower sublethal concentrations of carbaryl (i.e. 0.04 and 0.06%) caused 0.7

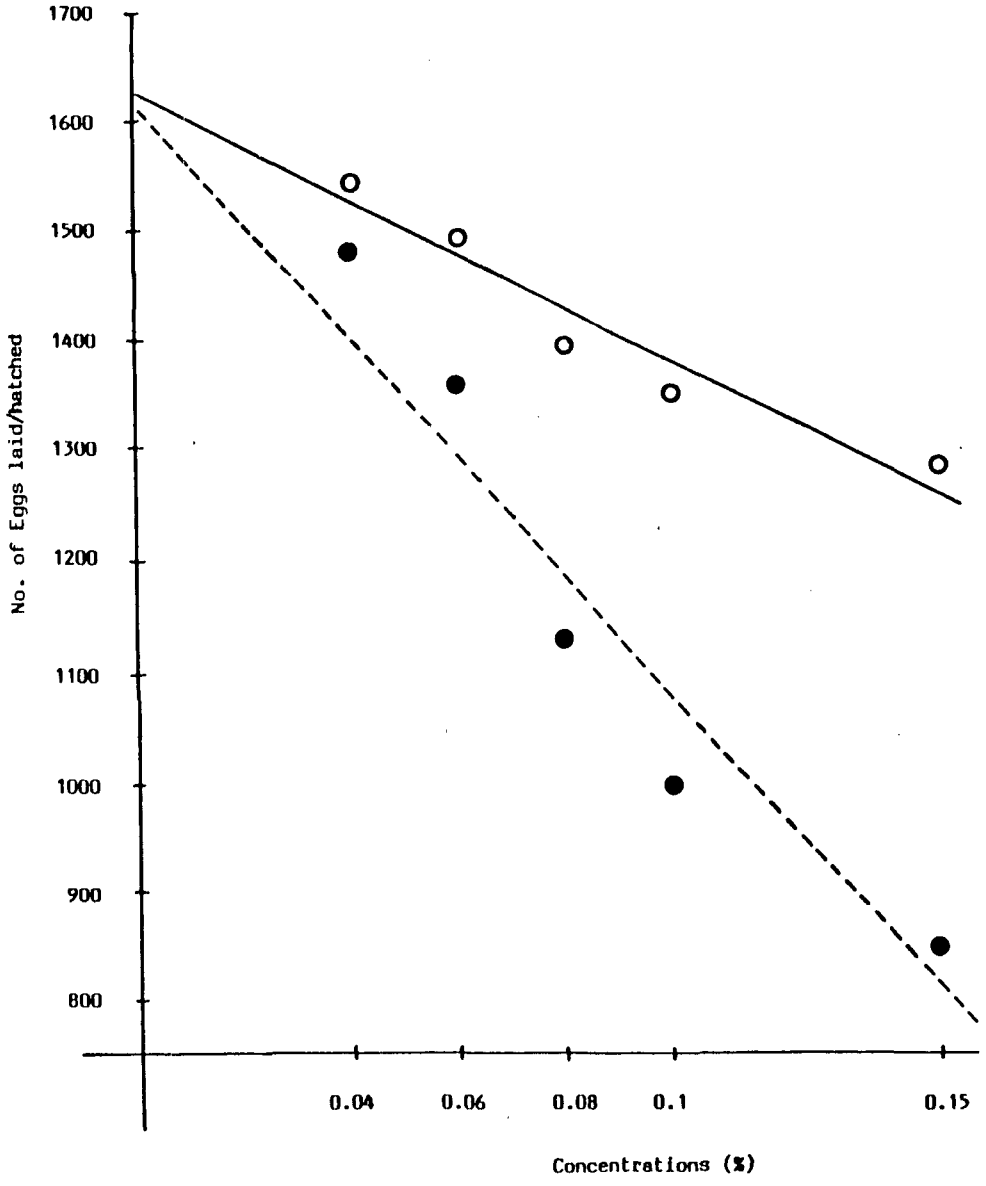

Fig.21. Linear reduction in fecundity (O) and fertility (●) of *D. obliqua* females emerged from 5th instar treated larvae following topical application of different concentrations of carbaryl.

(t=1.6536, p>0.05) and 5.71% (t=2.4227, p>0.05) drop in the average viability of the eggs, respectively, as compared to control-I (Table-21). Whereas the average hatchability of the eggs after the application of 0.8, 0.1 and 0.15% carbaryl/5th instar larva was reduced by 15.71 (t=3.5411, p<0.05), 22.7 (t=4.2342, p<0.05) and 30.71% (t=4.5326, p<0.05), respectively, as compared to control-I (Table-21).

11.2. Effects of Topical Application of Sublethal Concentrations of Carbaryl on 6th Instar Larvae of *Diacrisia obliqua* Wlk.

11.2.1. Mortality, Moulting and Longevity

In the first set, out of the 100 treated larvae(6th instar), the total loss of life up to adult emergence was 5% which was only 1% more as compared to control-II. In this experiment also the difference in mortality between control-I and-II was insignificant, therefore, further reference was made only to control-II for comparison. When each of 100 6th instar larvae had topical application of the lowest (0.04%) sublethal concentration of carbaryl (set two), there was no significant loss either within the 6th instar or up to adult emergence. There was only 2% more loss up to adult emergence as compared to control-I. The adults which emerged from the survived larvae were healthy, active and normal morphologically. In the third set where each of the 100 larvae was applied with 0.06% carbaryl, 7 died within the same instar, whereas, 4 lost their lives in the pupal stage showing a drop of 6% more in adults, as compared to control-I. In the set fourth of this experiment, where each of 100 larvae was applied with 0.08% carbaryl, the mortality was 14 within the 6th instar, 4 during larval-pupal transformation with incomplete moulting and 2 in the pupal stage. Hence, there was a total loss of 20% up to adult emergence which was 15% more as compared to control-I (Table-22). In the fifth set, each of 100 6th instar larvae (one day old) was topically treated with 0.1% carbaryl, 24 larvae died within the same instar, whereas, 3 and 5 lost their life at larval-pupal transformation and in pupal stage, respectively. The total loss in adult emergence following the topical application of 0.1% carbaryl was 27% more, as compared to control-I. Out of the

total emerged adults from the treated larvae, 6.1% were with malformed wings. In the sixth set of 100 larvae treated with 0.15% carbaryl there were 32 mortalities within the same instar, 8 at larval-pupal transformation and 3 in pupal stage respectively. Therefore, the total fall in adult emergence was 39% more as compared to control-I (Table-22). Among the adults which emerged from the treated larvae, 10.3% had malformed wings. These malformed adults were weak and lethargic. The average longevity of 6th instar larvae was increased by 10%, whereas, the average pupal duration of these affected larvae was enhanced by 26%. The mean life span of adult males and females was prolonged by 29 and 19%, respectively, as compared to control-I (Table-35).

11.2.2. Fecundity and fertility

The active, normal and healthy males of each set were allowed to mate with the virgin females of their respective group and each pair was kept separately. The average fecundity of the females after the topical application of the aforesaid concentrations of carbaryl dropped linearly ($Y=1642.86 - 1993.47 X$, $r= - 0.9452$, $p<0.05$) and yielded a negative correlation with increasing concentrations (fig.22). The topical application of the lowest sublethal concentration (0.04%) of carbaryl/larva, however, exhibited a stimulatory effect on the egg production of the females and resulted in 1.06% ($t=1.0872$, $p>0.05$) increase in the average egg production as compared to control-I (Table-22). But the topical application of 0.06 and 0.08% carbaryl showed inhibitory effect on the average egg production by the affected females and resulted in 5.03 ($t=1.4571$, $p>0.05$) and 9.01% ($t=2.0371$, $p>0.05$) reduction, respectively, as compared to control-I (Table-22). Similarly, the topical application of 0.1 and 0.15% concentrations of carbaryl per 6th instar larva also showed 11.99 ($t=2.3369$, $p>0.05$) and 16.02% ($t=2.5799$, $p<0.05$) decrease in the average egg production by the affected females, respectively, as compared to control-I (Table-22).

The fertility of the eggs laid by the affected females after the topical application of the aforesaid concentrations of carbaryl also declined linearly ($Y=1608.45 - 4638.89 X$, $r= - 0.9825$, $p<0.05$) and yielded a negative correlation with

increase in concentration strength (fig.22). The topical application of the lower sublethal concentrations i.e. 0.04 and 0.06% carbaryl per 6th instar larvae of *D. obliqua* resulted in 2.6 ($t=1.4949$, $p>0.05$) and 5.61% ($t=2.0269$, $p>0.05$) reduction in the average hatchability of the eggs laid by the affected females, respectively, as compared to control-I (Table-22). Whereas a significant fall in the viability of the eggs was recorded following the topical application of higher selected sublethal concentrations. After the topical application of 0.08, 0.1 and 0.15% concentrations of carbaryl, the average viability of the eggs was significantly reduced by 18.76 ($t=2.9700$, $p<0.05$), 18.6 ($t=3.5419$, $p<0.05$) and 29.57% ($t=4.2035$, $p<0.05$), respectively, as compared to control-I (Table-22).

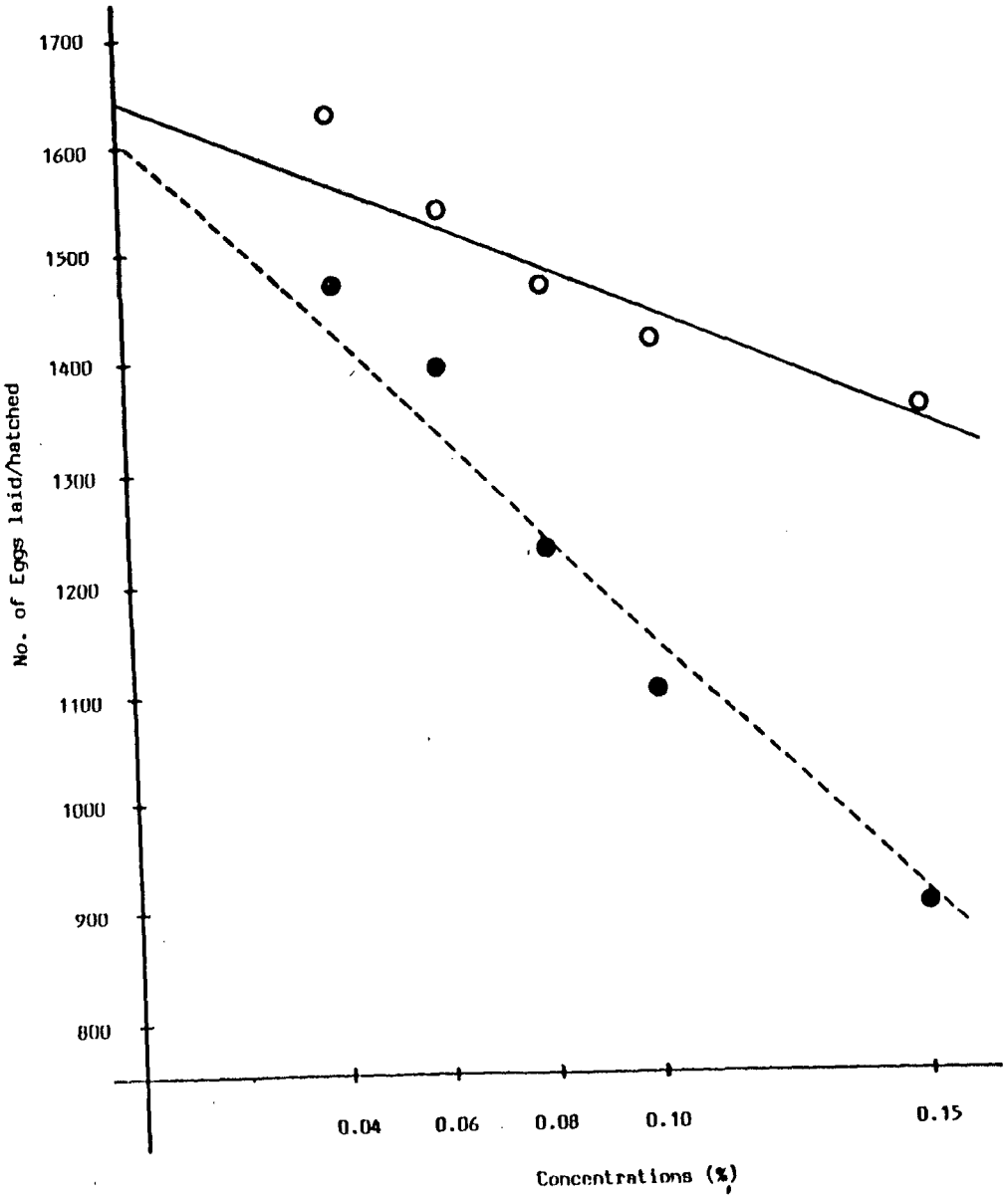

Fig.22. Linear reduction in fecundity (○) and fertility (●) of *D. obliqua* females emerged from 6th instar treated larvae following topical application of different concentrations of carbaryl.

12.1. Effects of Topical Application of Sublethal Concentrations of Aminocarb on 5th Instar Larvae of *Diacrisia obliqua* Wlk.

12.1.1. Mortality, Moulting and Longevity

In the first set (control-I), where each of the 100 (5th instar) larva was treated with 2µl acetone (solvent) only, the total larval loss up to adult emergence was 4% which was only 1% more as compared to control-II. The adults which emerged from the treated larvae were active, healthy and normal morphologically as those adults which emerged from the untreated larvae. As the difference between acetone treated (control-I) and untreated (control-II) sets was insignificant, further reference was made with control-I. In the second set of 100 larvae, each of which was topically treated with the lowest sublethal concentration (0.08%), the total larval and pupal loss up to adult emergence was 7% more as compared to control-I (Table-23). The adults which emerged from the treated larvae were active and healthy. In the third set, where each of the 100 larvae was topically treated with 0.1% aminocarb, the total larval and pupal loss up to adult emergence was 3% less as compared to that of the lowest selected sublethal concentration (0.08%), but this loss was 4% more as compared to control-I. The adults which emerged from the treated larvae were healthy, active and normal. In the fourth set of 100 larvae (5th instar), each treated topically with 0.15% aminocarb, 15 died within the same instar, whereas, 2 larvae could not survive while moulting to the next (6th) instar. Further, mortality of 1 and 3 individuals occurred at larval-pupal ecdysis and pupal stage, respectively. Consequently the total loss of life upto adult emergence was 17% more as compared to control-I (Table-23). Out of the adults which emerged from the survived treated larvae 2.9% were with malformed wings. In the fifth set of 100 larvae when each was topically treated with 0.2% aminocarb, 21 larvae died during the same stage, 4 in the 6th instar, 6 at larval-pupal transformation and 5 at pupal stage giving total loss of 32% more as compared to control-I (Table-23). Out of the emerged adults from treated larvae, 6.7% were with malformed wings. In the sixth set, the topical application of 0.25% aminocarb per 5th instar larva resulted in mortality of 34 larvae within the same instar, 1 in the 6th instar, 11 at the larval-pupal

transformation and 8 individuals within the pupal stage, thereby, the total loss of larvae upto adult emergence was 50% more as compared to control-I (Table-23). Out of the emerged adults from the treated larvae, 11.3% were with malformed wings. These adults were weak, lethargic and not as compatible as normal adults. The average larval duration of 5^{th} and 6^{th} instar was increased by 13 and 18%, respectively, as compared to control-I (93.6 and 142.8 hrs., respectively). The average pupal duration of these affected larvae was enhanced by 21%, whereas, the mean life span of adult males and females was prolonged by 11 and 10%, respectively, as compared to control-I (Table-36).

12.1.2. Fecundity and Fertility

The active, healthy and normal males of each set were allowed to mate with virgin females of their respective sets. Then the average fecundity of the affected females emerged following the topical application of aforesaid concentrations dropped linearly with regard to higher strengths ($Y=1659.18 - 1136.0 X$, $r= - 0.9772$, $p<0.05$) and yielded a negative correlation (fig.23). Following the topical application of 0.08, 0.10, 0.15 and 0.20% aminocarb, the average fecundity of the emerged females was reduced by 3.0 ($t=1.1145$, $p>0.05$), 5.38 ($t=1.5624$, $p>0.05$), 6.91 ($t=1.7378$, $p>0.05$) and 13.03% ($t=2.3925$, $p>0.05$), respectively, as compared to control-I (Table-23) which were statistically insignificant. But the average egg production of the emerged affected females after the topical application of the highest selected sublethal concentration (0.25%) was 17.01% ($t=2.9346$, $p<0.05$) less as compared to control-I (Table-23).

The fertility of the eggs laid by the affected females following the topical application of the aforesaid concentrations also reduced linearly ($Y = 1674.4 - 2278.74 X$, $r= - 0.9648$, $p<0.05$) with increase in concentration and yielded a negative correlation (fig.23). Following the topical application of 0.08, 0.10 and 0.15% aminocarb, the average hatchability of the eggs laid by the affected females reduced insignificantly by 0.8 ($t=1.3385$, $p>0.05$), 0.51 ($t=2.3149$, $p>0.05$) and 6.8% ($t=2.5251$, $p>0.05$), respectively, as compared to control-I (Table-23). On the other hand, the topical application of 0.2 and 0.25% aminocarb/larva developed

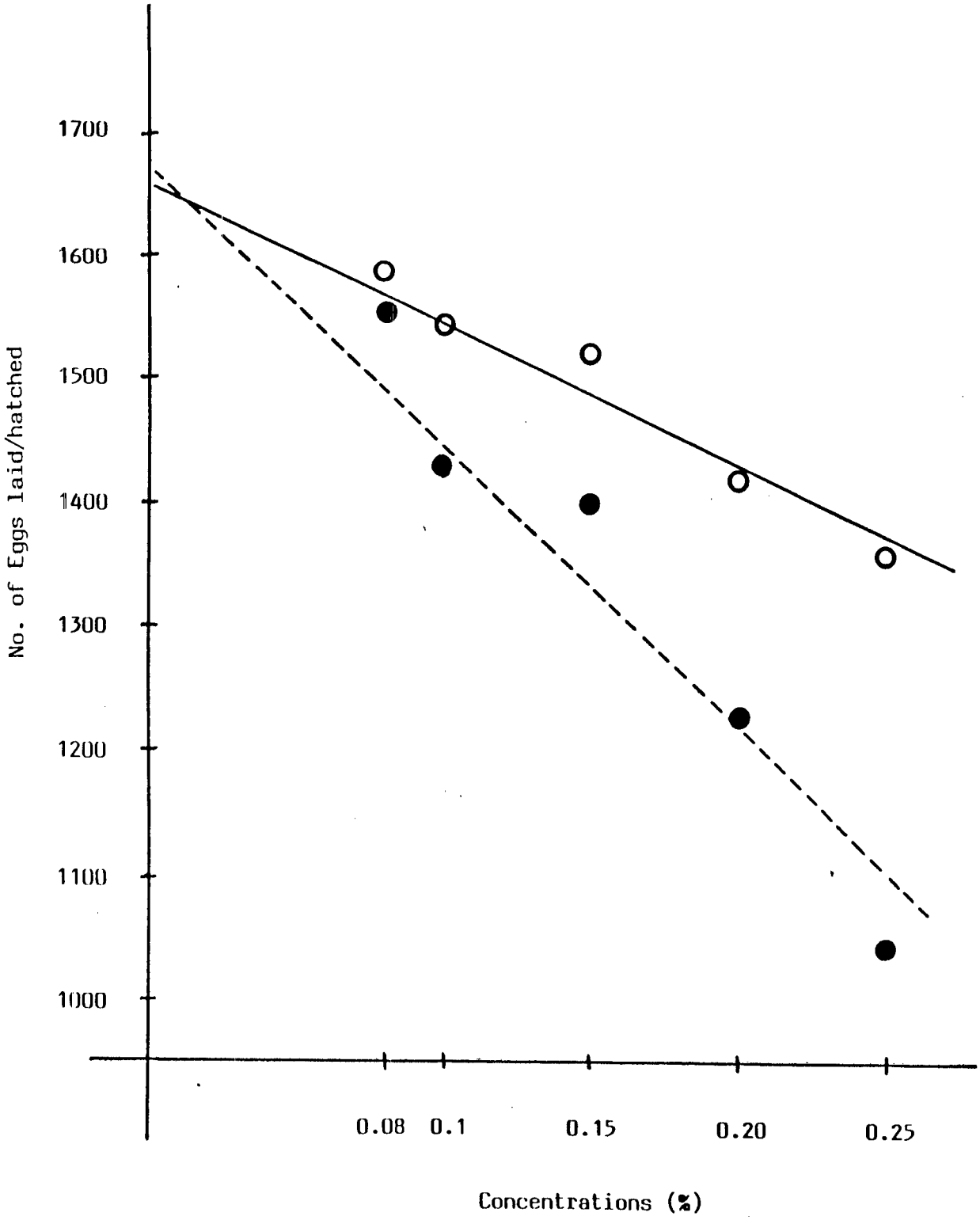

Fig.23. Linear reduction in fecundity (o) and fertility (●) of *D. obliqua* females emerged from 5th instar treated larvae following topical application of different concentrations of aminocarb.

significant reduction in egg viability by 12.77 ($t=3.3385$, $p<0.05$) and 21.77% ($t=4.0116$, $p<0.05$), respectively, as compared to control-I (Table-23).

12.2. Effects of Topical Application of Sublethal Concentrations of Aminocarb on the 6th Instar Larvae of *Diacrisia obliqua* Wlk.

12.2.1. Mortality, Moulting and Longevity

In first set of 100 larvae (one day old), the total loss up to adult emergence was 6% which was 2% higher than that of control-II. As the difference in mortality between the two controls was insignificant, therefore further reference was made only to control-I for comparison. The adults which emerged from the treated larvae were healthy, active and normal morphologically. In the second set of 100 larvae, which were individually applied with 0.08% aminocarb, there was mortality of 4 larvae within the same instar, 1 at larval-pupal transformation, resulting in total loss of 5% which was 1% less as compared to control-I (Table-24). In the third set, the topical application of 0.1% aminocarb/larva caused death to 3 larvae during the 6th instar, and 4 within the pupal stage, leading to 7% loss of life up to adult emergence which was only 1% more as compared to control-I (Table-24). In the fourth set, when each of the 100 larvae was applied with 0.15% aminocarb, 8 larvae died in the same instar, whereas, 4 could not transform to pupal stage completely and died at larval-pupal transformation stage. Further, 2 individual died at pupal stage, resulting in 8% more loss of life up to adult emergence as compared to control-I. In the fifth set, when each of the 100 larvae was topically treated with 0.2% aminocarb, the mortality was 17 in the present instar (6th stage), 2 at larval-pupal transformation and 4 during pupal stage, thereby, enhancing the larval and pupal loss by 17% up to adult emergence as compared to control-I. Among the adults, 5.7% were with malformed wings. In the sixth set of this experiment, the topical application of 0.25% aminocarb resulted in mortality of 23 larvae within the same instar, 5 at larval-pupal transformation and 6 in pupal stage. The total loss of larvae upto adult emergence was 25% more as compared to control-I (Table-24). Out of the emerged adults from

the treated larvae, 8.2% were with malformed wings. The longevity of 6th instar larvae was increased by 24.7% as compared to control-I (130.8 hrs.), whereas, the average pupal duration as well as the mean life span of adult males and females was prolonged by 38, 30, and 15%, respectively, as compared to control-I (Table-36).

12.2.2. Fecundity and Fertility

The males of each set which were, normal, active and healthy were allowed to mate with their respective virgin females by keeping each pair separately. The average egg production of the females which emerged from the treated larvae following the topical application of the aforesaid concentrations dropped linearly ($Y=1653.45 -695.75 X$, $r= - 0.9763$, $p<0.05$) with negative correlation (fig.24). The topical application of 0.08% aminocarb per 6th instar larva showed a 4.01% ($t=1.2912$, $p>0.05$) reduction in the average egg production of the females emerged from the survived treated larvae as compared to control-I (Table-24). Whereas the average egg production of the females after the topical application of 0.1% aminocarb was reduced by 2.97% ($t=1.1496$, $p>0.05$) as compared to control-I (Table-24). Further, the topical application of 0.15% aminocarb/larva resulted in 4.98% ($t=1.4729$, $p>0.05$) loss in the average fecundity of the females as compared to control-I (Table-24). Whereas with respect to topical application of 0.20% and 0.25% aminocarb on 6th instar larvae, the fall in fecundity was 8.01 ($t=1.8562$, $p>0.05$) and 10.98% ($t=2.2695$, $p>0.05$), respectively, as compared to control-I (Table-24).

The fertility of the eggs laid by the affected females emerged following the topical application of the aforesaid concentrations on the 6th instar larvae declined linearly with stronger concentrations of this chemical ($Y=1662.72 - 1752.99 X$, $r= - 0.9474$, $p<0.05$) and there was negative correlation (fig.24). Following the topical application of 0.08, 0.10 and 0.15% Aminocarb, the average hatching of the eggs dropped insignificantly by 0.36, 2.4 and 3.4% ($t=1.3822$, 1.5020 and 1.7017, $p>0.05$), respectively, as compared to control-I (Table-24). Whereas the average viability of the eggs laid by affected females following the topical application of 0.20 and 0.25

aminocarb decreased by 10.38 and 18.39% (t=2.9084, 3.4381, $p<0.05$), respectively, as compared to control-I (Table-24).

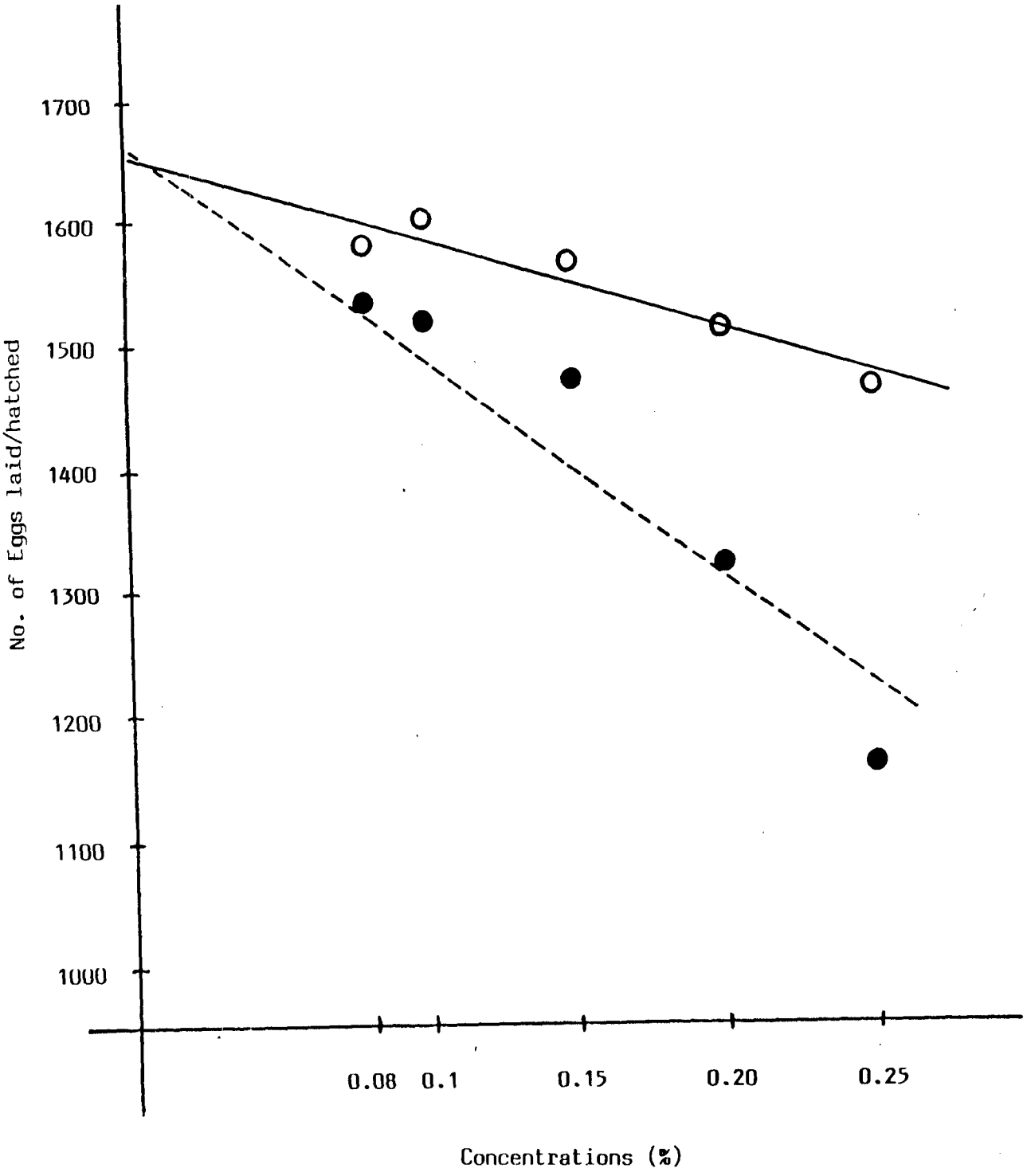

Fig.24. Linear reduction in fecundity (o) and fertility (●) of *D. obliqua* females emerged from 6th instar treated larvae following topical application of different concentrations of aminocarb.

TABLE- No. 1

Nymphal mortality, fecundity and egg viability of *Dysdercus cingulatus* following the topical application of different sublethal concentrations of acephate on 4th instar nymphs (24 hrs old).

Concentrations (%), 1µ/nymph	MORTALITY						Number of eggs laid (Mean ± S.E)	Number of eggs hatched (Mean ± S.E)	% Hatching
	During 4th instar	At 4th-5th instar moulting	During 5th instar	At nymphal-adult moulting	% Nymphal loss up to adult emergence	% Adult emergence			
0.002	43	07	05	01	56	44	333±7.75	243±7.65	72.97
0.001	31	04	03	03	41	59	359±5.38	287±9.23	79.94
0.0008	19	05	01	00	25	75	379±5.48	329±6.01	86.81
0.0006	10	00	02	01	13	87	390±5.27	356±8.28	91.28
0.0004	03	01	00	03	07	96	412±6.99	396±8.11	96.12
Solvent treated (Control-I)	02	00	00	01	03	97	426±3.72	421±5.49	98.83
Untreated (Control-II)	03	00	00	00	03	97	421±2.61	417±2.28	99.05

TABLE-2

Nymphal mortality, fecundity and egg viability of *Dysdercus cingulatus* following the topical application of different sublethal concentrations of acephate on 5th instar nymphs (24 hrs old).

Concentratios (%) 1µl/nymph	MORTALITY				No. of eggs laid (Mean ± S.E.)	No. of eggs hatched (Mean ± S.E.)	% Hatching
	During 5th instar	During nymphal-adult moulting	% Nymphal loss up to adult emergence	% Adult emergence			
0.002	30	09	39	61	361±5.46	285±10.14	78.95
0.001	21	05	26	74	380±8.78	323±11.24	85.00
0.0008	18	02	20	80	389±8.71	342±6.25	87.92
0.0006	09	03	12	88	405±6.47	377±7.96	93.09
0.0004	02	00	02	98	410±9.34	407±7.45	99.27
Solvent (Control-I)	03	00	03	97	418±2.88	411±8.13	98.33
Untreated (Control-II)	02	00	02	98	414±7.30	409±4.96	98.79

TABLE- No. 3

Nymphal mortality, fecundity and egg viability of *Dysdercus cingulatus* following the topical application of different sublethal concentrations of ethion on 4th instar nymphs (24 hrs old)

Concentrations (%), 1µl /nymph	MORTALITY						Number of eggs laid (Mean ± S.E)	Number of eggs hatched (Mean ± S.E)	% Hatching
	During 4th instar	At 4th -5th instar moulting	During 5th instar	At nymphal-adult moulting	% Nymphal loss up to adult emergence	% Adult Emergence			
0.006	40	03	06	02	51	49	339±7.95	292±9.01	86.14
0.004	29	05	03	03	40	60	345±10.42	309±8.10	89.57
0.002	15	04	00	01	20	80	368±15.05	345±11.79	93.75
0.001	09	02	03	00	14	86	390±14.38	381±10.68	97.69
0.0008	05	00	00	00	05	95	385±9.41	381±14.88	98.96
Solvent treated (Control-I)	03	00	01	00	04	96	400±4.5	389±11.11	97.25
Untreated (Control-II)	04	00	00	00	04	96	401±5.62	394±7.36	98.25

TABLE-4

Nymphal mortality, fecundity and egg viability of *Dysdercus cingulatus* following the topical application of different sublethal concentrations of ethion on 5th instar nymphs (24 hrs old).

Concentratios (%) 1µl/nymph	MORTALITY				No. of eggs laid (Mean ± S.E.)	No. of eggs hatched (Mean ± S.E.)	% Hatching
	During 5th instar	During nymphal-adult moulting	% Nymphal loss up to adult emergence	% Adult emergence			
0.006	29	05	34	66	351±8.41	298±10.15	84.90
0.004	22	06	28	72	359±10.40	323±10.88	89.97
0.002	13	03	16	84	379±9.19	352±13.35	92.88
0.001	07	04	11	89	387±16.13	368±6.71	95.09
0.0008	03	00	03	97	411±9.85	383±8.22	96.96
Solvent treated (Control-I)	04	00	04	96	403±5.37	397±4.56	98.51
Untreated (Control-II)	01	01	02	98	399±5.42	395±7.19	98.99

TABLE- No. 5

Nymphal mortality, fecundity and egg viability of *Dysdercus cingulatus* following the topical application of different subiethal concentrations of dichlorvos on 4th instar nymphs (24 hrs old)

Concentrations (%), 1µl /nymph	MORTALITY						Number of eggs laid (Mean ± S.E)	Number of eggs hatched (Mean ± S.E)	% Hatching
	During 4th instar	At 4th-5th instar moulting	During 5th instar	At nymphal-adult moulting	% Nymphal loss up to adult emergence	% Adult emergence			
0.01	41	05	03	05	54	46	339±12.33	281±8.28	82.89
0.008	30	06	05	02	43	57	355±7.71	305±11.02	85.92
0.006	22	06	02	00	30	70	332±6.57	309±10.76	93.07
0.004	13	03	00	01	17	83	374±7.03	371±8.19	99.20
0.002	08	02	01	00	11	89	381±10.26	377±6.46	98.05
Solvent treated (Control-I)	04	00	01	00	05	95	390±5.28	383±4.65	98.21
Untreated (Control-II)	02	01	00	00	03	97	394±3.98	382±6.79	96.95

TABLE-6

Nymphal mortality, fecundity and egg viability of *Dysdercus cingulatus* following the topical application of different sublethal concentrations of dichlorvos on 5th instar nymphs (24 hrs old).

Concentratios (%) 1µl/ nymph	MORTALITY				No. of eggs laid (Mean ± S.E.)	No. of eggs hatched (Mean ± S.E.)	% Hatching
	During 5th instar	During nymphal-adult moulting	% Nymphal loss up to adult emergence	% Adult emergence			
0.01	31	01	32	68	352±7.91	302±10.15	85.80
0.008	27	03	30	70	367±7.87	333±11.07	90.74
0.006	16	07	23	77	371±11.66	352±8.48	94.88
0.004	07	02	09	91	383±8.60	372±8.61	97.13
0.002	05	01	06	94	387±10.65	375±9.75	96.90
Solvent (Control-I)	02	01	03	97	395±5.19	382±9.33	96.71
Untreated (Control-II)	00	01	01	99	397±9.76	392±7.60	98.74

TABLE- No. 7

Nymphal mortality, fecundity and egg viability of *Dysdercus cingulatus* following the tropical application of different sublethal concentrations of furadan on 4th instar nymphs (24 hrs old).

Concentrations (%), 1µl /nymph	MORTALITY						Number of eggs laid (Mean ± S.E)	Number of eggs hatched (Mean ± S.E)	% Hatching
	During 4th instar	At 4th-5th instar moulting	During 5th instar	At nymphal-adult moulting	% Nymphal loss up to adult emergence	% Adult emergence			
0.001	46	04	05	02	57	43	192±5.57	80±9.65	41.67
0.0008	29	06	03	06	44	56	233±6.65	126±8.88	54.08
0.0006	20	04	04	01	29	71	274±5.24	169±8.96	61.68
0.0004	15	00	03	00	18	82	327±5.83	242±10.91	74.01
0.0002	07	00	00	01	08	92	353±5.12	321±8.70	90.93
Solvent treated (Control-I)	04	00	00	00	04	96	376±4.52	365±7.71	97.07
Untreated (Control-II)	00	00	00	00	02	98	374±6.89	367±4.60	98.13

TABLE-8

Nymphal mortality, fecundity and egg viability of *Dysdercus cingulatus* following the topical application of different sublethal concentrations of furadan on 5th instar nymphs (24 hrs old).

Concentratios (%) 1µl/nymph	MORTALITY				No. of eggs laid (Mean ± S.E.)	No. of eggs hatched (Mean ± S.E.)	% Hatching
	During 5th instar	During nymphal-adult moulting	% Nymphal loss up to adult emergence	% Adult emergence			
0.001	32	11	43	57	225±5.48	119±4.69	52.89
0.0008	25	07	32	68	251±8.68	153±7.73	60.96
0.0006	18	04	22	78	273±5.25	188±5.00	68.86
0.0004	10	04	14	86	305±4.74	259±8.81	84.92
0.0002	07	03	10	90	362±9.17	329±5.22	90.88
Solvent (Control-I)	03	03	06	96	381±6.16	366±4.76	96.06
Untreated (Control-II)	04	01	05	95	384±2.55	375±3.91	97.66

TABLE- No. 9

Nymphal mortality, fecundity and egg viability of *Dysdercus cingulatus* following the topical application of different sublethal concentrations of carbaryl on 4th instar nymphs (24 hrs old).

Concentrations (%) 1µl /nymph	MORTALITY						Number of eggs laid (Mean ± S.E)	Number of eggs hatched (Mean ± S.E)	% Hatching
	During 4th instar	At 4th-5th instar moulting	During 5th instar	At nymphal-adult moulting	% Nymphal loss up to adult emergence	% Adult emergence			
0.0025	44	03	02	04	53	47	250±7.99	160±7.46	64.00
0.002	28	02	04	03	37	63	291±6.49	226±5.33	77.66
0.0015	17	01	01	01	20	80	310±4.96	263±6.01	84.84
0.001	07	00	01	03	11	8/9	324±10.48	282±5.75	87.04
0.0005	03	00	00	00	03	97	334±9.62	304±6.24	91.02
Solvent treated (Control-I)	01	00	01	02	04	96	352±8.07	340±4.31	96.59
Untreated (Control-II)	00	00	02	00	02	98	355±6.25	339±4.69	95.49

TABLE-10

Nymphal mortality, fecundity and egg viability of *Dysdercus cingulatus* following the topical application of different subiethal concentrations of carbaryl on 5th instar nymphs (24 hrs old).

Concentratios (%) 1µl/nymph	MORTALITY				No. of eggs laid (Mean ± S.E.)	No. of eggs hatched (Mean ± S.E.)	% Hatching
	During 5th instar	During nymphal-adult moulting	% Nymphal loss up to adult emergence	% Adult emergence			
0.0025	32	03	35	65	265±4.58	196±6.57	73.96
0.002	16	05	21	79	286±5.45	232±13.32	81.12
0.0015	11	04	15	85	303±5.00	261±9.41	86.14
0.001	05	06	11	89	320±7.47	394±7.32	91.88
0.0005	04	04	08	92	329±4.96	316±5.46	96.05
Solvent (Control-I)	01	03	03	97	340±5.72	333±6.16	97.94
Untreated (Control-II)	03	01	04	96	337±4.17	327±5.02	97.03

TABLE- No. 11

Nymphal mortality, fecundity and egg viability of *Dysdercus cingulatus* following the topical application of different sublethal concentrations of aminocarb on 4th instar nymphs (24 hrs old).

Concentrations (%), 1µl /nymph	MORTALITY						Number of eggs laid (Mean ± S.E)	Number of eggs hatched (Mean ± S.E)	% Hatching
	During 4th instar	At 4th-5th instar moulting	During 5th instar	At nymphal-adult moulting	% Nymphal loss up to adult emergence	% Adult emergence			
0.004	38	02	05	04	49	51	290±5.22	226±4.19	77.93
0.002	27	01	07	02	37	63	302±7.66	243±6.20	80.46
0.001	18	00	03	06	27	73	331±10.98	291±5.04	87.92
0.0008	11	01	04	00	16	84	346±5.24	325±5.78	93.93
0.0006	07	00	02	01	10	90	353±10.01	339±5.06	96.03
Solvent treated (Control-I)	01	00	02	03	06	94	360±4.15	355±6.42	98.61
Untreated (Control-II)	01	00	01	01	03	97	362±6.33	351±4.52	96.96

TABLE-12

Nymphal mortality, fecundity and egg viability of *Dysdercus cingulatus* following the topical application of different sublethal concentrations of aminocarb on 5th instar nymphs (24 hrs old).

Concentratios (%) 1µl/nymph	MORTALITY				No. of eggs laid (Mean ± S.E.)	No. of eggs hatched (Mean ± S.E.)	% hatching
	During 5th instar	During nymphal-adult moulting	% Nymphal loss upto adult emergence	% Adult emergence			
0.004	33	03	36	64	309±5.69	244±7.16	78.96
0.002	20	07	27	73	324±7.63	282±6.13	87.04
0.001	13	05	18	82	339±7.47	299±7.04	88.20
0.0008	09	04	13	87	328±7.53	325±7.14	93.93
0.0006	06	03	09	91	351±7.85	346±6.09	96.92
Solvent (Control-I)	04	02	06	94	364±5.02	360±5.22	98.90
Untreated (Control-II)	01	02	03	97	361±5.64	352±5.08	97.51

TABLE- No. 13

Larval mortality, fecundity and egg viability of *Diacrisia obliqua* following the topical application of different sub lethal concentrations of acephate on 5th instar larvae (24 hrs old)

Concentrations (%) 2µl/ larva	MORTALITY						Number of eggs laid (Mean ± S.E)	Number of eggs hatched (Mean ± S.E)	% Hatching
	During 5th instar	During 6th instar	At larval-pupal transformation	At pupal stage	% Larval loss up to adult emergence	% Adult emergence			
0.1	35	03	09	06	53	43	1604±44.26	1395±62.89	86.97
0.08	24	01	07	08	40	60	1692±46.74	1574±76.09	93.08
0.06	15	00	08	03	26	74	1724±57.46	1638±57.46	95.04
0.04	09	00	02	00	11	89	1789±72.68	1735±65.19	96.98
0.02	04	00	06	01	07	93	1838±62.04	1764±61.19	95.97
Solvent treated (Control-I)	00	00	01	01	02	98	1870±21.16	1850±20.79	98.93
Untreated (Control-II)	00	00	01	02	03	97	1865±16.49	1837±17.91	98.49

TABLE-14

Larval mortality, fecundity and egg viability of *Diacrisia obliqua* following the topical application of different sublethal concentrations of acephate on 6th instar larvae (24 hrs old)

Concentrations (%) 2 µl/ larva	MORTALITY					No. of eggs laid (Mean ± S.E)	No. of eggs hatched (Mean ± S.E)	% Hatching
	During 6th instar	At larval-pupal transformation	At pupal stage	% Larval loss up to adult emergence	% Adult emergene			
0.1	20	09	05	34	66	1505±51.75	1279±61.88	84.98
0.08	19	05	03	27	73	1669±44.35	1502±43.07	89.99
0.06	06	07	04	17	83	1688±42.76	1569±41.42	92.95
0.04	04	02	00	06	94	1762±40.79	1656±41.44	93.98
0.02	03	00	00	03	97	1743±63.36	1691±49.56	97.02
Solvent treated (Control-I)	00	03	03	04	96	1835±37.95	1780±14.06	97.00
Untreated (Control-II)	01	01	00	01	99	1815±21.93	1799±23.35	99.12

TABLE- No. 15

Larval mortality, fecundity and egg viability of *Diacrisia obliqua* following the topical application of different sublethal concentrations of ethion on 5th instar larvae (24 hrs old).

Concentrations (%) 2µl / larva	MORTALITY						Number of eggs laid (Mean ± S.E)	Number of eggs hatched (Mean ± S.E)	% Hatching
	During 5th instar	During 6th instar	At larval-pupal transformation	At pupal stage	% Larval loss up to adult emergence	% Adult emergence			
0.6	38	02	12	05	57	43	1488±48.06	1246±48.40	83.74
0.4	24	02	09	04	39	61	1615±42.35	1371±47.53	84.89
0.2	16	03	07	02	28	75	1652±31.92	1454±58.03	88.01
0.1	09	01	08	01	19	81	1706±33.44	1570±46.41	92.03
0.08	05	00	02	04	11	89	1833±46.51	1690±44.90	94.99
Solvent treated (Control-I)	02	00	01	02	05	95	1815±27.79	1761±16.42	97.02
Untreated (Control-II)	01	00	00	01	02	98	1802±27.42	1766±16.29	98.00

TABLE-16

Larval mortality, fecundity and egg viability of *Diacrisia obliqua* following the topical application of different sublethal concentrations of ethion on 6th instar larvae (24 hrs old)

Concentrations (%) 2 µl/ larva	MORTALITY					No. of eggs laid (Mean ± S.E)	No. of eggs hatched (Mean ± S.E)	% Hatching
	During 6th instar	At larval-pupal transformation	At pupal stage	% Larval loss up to adult emergence	% Adult emergene			
0.6	29	08	04	41	59	1529±40.04	1269±34.02	82.99
0.4	23	04	03	30	70	1584±59.12	1362±37.81	85.98
0.2	09	04	05	18	82	1656±33.76	1507±43.69	91.00
0.1	06	03	01	10	90	1710±42.63	1643±41.69	96.08
0.08	03	01	00	04	96	1692±47.27	1605±38.70	94.86
Solvent treated (Control-I)	01	00	00	01	99	1801±16.96	1782±22.15	98.95
Untreated (Control-II)	00	01	00	01	99	1789±11.56	1717±14.16	95.96

TABLE- No. 17

Larval mortality, fecundity and egg viability of *Diacrisia obliqua* following the topical application of different sub lethal concentrations of Dichlorvos on 5th instar larvae (24 hrs old).

Concentrations (%) 2µl / larva	MORTALITY						Number of eggs laid (Mean ± S.E)	Number of eggs hatched (Mean ± S.E)	% Hatching
	During 5th instar	During 6th instar	At larval-pupal transformation	At pupal stage	% Larval loss up to adult emergence	% Adult emergence			
0.4	41	03	07	04	55	45	1362±43.17	1104±46.72	81.06
0.2	32	02	05	07	46	54	1487±50.16	1234±52.02	82.99
0.1	26	04	03	01	34	66	1628±35.90	1465±35.65	89.99
0.08	14	05	00	01	20	80	1682±45.05	1564±36.05	92.98
0.06	07	00	02	00	09	89	1718±51.44	1649±27.03	95.98
Solvent treated (Control-I)	00	00	03	01	04	96	1770±12.43	1718±10.59	97.06
Untreated (Control-II)	01	00	02	02	05	95	1785±11.32	1751±17.35	98.00

TABLE-18

Larval mortality, fecundity and egg viability of *Diacrisia obliqua* following the topical application of different sublethal concentrations of dichlorvos on 6th instar larvae (24 hrs old)

Concentrations (%) 2 µl/ larva	MORTALITY					No. of eggs laid (Mean ± S.E)	No. of eggs hatched (Mean ± S.E)	% Hatching
	During 6th instar	At larval-pupal transformation	At pupal stage	% Larval loss up to adult emergence	% Adult emergence			
0.4	28	06	03	37	63	1416±28.89	1119±34.52	79.03
0.2	21	04	06	31	69	1521±32.96	1262±48.30	82.97
0.1	15	07	01	23	77	1577±36.93	1356±37.15	85.99
0.08	09	00	04	13	87	1626±32.71	1480±51.09	91.02
0.06	05	01	01	07	93	1664±38.59	1564±38.02	93.99
Solvent treated (Control-I)	00	00	01	01	99	1751±13.89	1747±31.23	99.77
Untreated (Control-II)	00	01	02	03	97	1737±15.49	1698±12.62	97.75

TABLE- No.19

Larval mortality, fecundity and egg viability of *Diacrisia obliqua* following the topical application of different sublethal concentrations of furadan on 5th instar larvae (24 hours old).

Concentrations (%) 2µl / larva	MORTALITY						Number of eggs laid (Mean ± S.E)	Number of eggs hatched (Mean ± S.E)	% Hatching
	During 5th instar	During 6th instar	At larval-pupal transformation	At pupal stage	% Larval loss up to adult emergence	% Adult emergence			
0.08	40	04	13	06	63	37	1040±68.89	0593±37.21	57.02
0.06	30	02	09	04	45	55	1176±62.02	0800±41.57	68.03
0.04	23	00	05	02	30	70	1330±74.39	0998±36.91	75.04
0.02	08	01	00	03	12	88	1483±70.59	1216±48.82	81.99
0.01	02	00	02	00	04	96	1586±53.89	1491±37.59	94.01
Solvent treated (Control-I)	02	01	01	01	05	95	1705±56.18	1671±39.37	98.01
Untreated (Control-II)	01	00	02	00	03	97	1712±33.01	1661±23.14	97.02

TABLE-20

Larval mortality, fecundity and egg viability of *Diacrisia obliqua* following the topical application of different sublethal concentrations of furadan on 6th instar larvae (24 hrs old)

Concentrations (%) 2 µl/ larva	MORTALITY					No. of eggs laid (Mean ±S.E)	No. of eggs hatched (Mean ± S.E)	% Hatching
	During 6th instar	At larval-pupal transformation	At pupal stage	% Larval loss up to adult emergence	% Adult emergence			
0.08	22	10	08	46	54	1148±42.41	0668±33.29	59.93
0.06	21	07	08	36	64	1268±54.51	0875±32.21	69.00
0.04	13	03	03	19	81	1405±51.97	1082±35.89	77.01
0.02	05	04	00	09	91	1559±35.93	1403±51.21	89.99
0.01	04	05	02	00	89	1610±53.33	1497±49.34	92.98
Solvent treated (Control-I)	00	01	01	02	98	1713±34.06	1694±36.34	98.89
Untreated (Control-II)	00	01	00	01	99	1726±31.07	1709±34.61	99.02

TABLE- No. 21

Larval mortality, fecundity and egg viability of *Diacrisia obliqua* following the topical application of different sublethal concentrations of carbaryl on 5th instar larvae (24 hrs old).

Concentrations (%) 2µl / larva	MORTALITY						Number of eggs laid (Mean ± S.E)	Number of eggs hatched (Mean ± S.E)	% Hatching
	During 5th instar	During 6th instar	At larval-pupal transformation	At pupal stage	% Larval loss up to adult emergence	% Adult emergence			
0.15	42	00	10	07	59	41	1284±5.68	0847±48.23	65.97
0.10	29	01	03	06	49	51	1349±59.43	0998±40.19	73.98
0.08	21	00	05	05	31	69	1398±61.43	1132±47.67	80.97
0.06	10	01	01	03	15	85	1495±59.17	1360±49.97	90.97
0.04	01	02	00	03	06	94	1544±52.37	1480±41.64	95.98
Solvent treated (Control-I)	00	00	03	00	03	97	1625±41.44	1571±38.11	96.68
Untreated (Control-II)	01	00	00	00	01	99	1620±29.79	1586±39.19	97.90

TABLE-22

Larval mortality, fecundity and egg viability of *Diacrisia obliqua* following the topical application of different sublethal concentrations of carbaryl on 6th instar larvae (24 hrs old)

Concentrations (%) 2 µl/ larva	MORTALITY					No. of eggs laid (Mean ± S.E)	No. of eggs hatched (Mean ± S.E)	% Hatching
	During 6th instar	At larval-pupal transformation	At pupal stage	% Larval loss up to adult emergence	% Adult emergence			
0.15	31	08	03	44	56	1352±51.11	0906±49.19	67.01
0.10	24	03	05	32	68	1417±42.73	1105±45.34	77.98
0.08	14	04	02	20	80	1465±41.75	1231±47.46	77.82
0.06	07	00	04	11	89	1529±49.63	1391±53.26	90.97
0.04	03	02	02	07	93	1627±55.64	1468±52.84	93.98
Solvent treated (Control-I)	01	01	03	05	95	1610±43.85	1555±42.54	96.58
Untreated (Control-II)	00	01	03	04	96	1603±38.79	1585±39.90	98.88

TABLE- No. 23

Larval mortality, fecundity and egg viability of *Diacrisia obliqua* following the topical application of different sublethal concentrations of aminocarb on 5th instar larvae (24 hrs old).

Concentrations (%) 2µl / larva	MORTALITY						Number of eggs laid (Mean ± S.E)	Number of eggs hatched (Mean ± S.E)	% Hatching
	During 5th instar	During 6th instar	At larval-pupal transformation	At pupal stage	% Larval loss up to adult emergence	% Adult emergence			
0.25	34	01	11	08	54	46	1357±40.87	1045±48.03	77.01
0.20	21	04	06	05	36	64	1422±52.95	1223±47.41	86.01
0.15	15	02	01	03	21	79	1522±53.45	1400±43.87	91.98
0.10	06	00	02	00	08	92	1547±50.09	1429±46.43	92.37
0.08	09	00	01	01	11	89	1586±58.42	1554±44.69	97.98
Solvent treated (Control-I)	02	00	02	00	04	96	1635±38.32	1615±38.75	98.78
Untreated (Control-II)	02	00	00	01	03	97	1668±30.31	1586±37.69	98.02

TABLE-24

Larval mortality, fecundity and egg viability of *Diacrisia obliqua* following the topical application of different sublethal concentrations of aminocarb on 6th instar larvae (24 hrs old)

Concentrations (%) 2 µl/ larva	MORTALITY					No. of eggs laid (Mean ± S.E)	No. of eggs hatched (Mean ± S.E)	% Hatching
	During 6th instar	At larval-pupal transformation	At pupal stage	% Larval loss up to adult emergence	% Adult emergence			
0.25	23	05	06	34	66	1467±44.67	1159±48.17	79.00
0.20	17	02	04	23	77	1516±52.46	1319±38.58	87.01
0.15	08	04	02	14	86	1566±51.21	1472±68.26	93.99
0.10	03	00	04	07	93	1599±49.44	1519±49.14	94.99
0.08	04	01	00	05	95	1582±55.58	1535±45.51	97.03
Solvent treated (Control-I)	02	03	01	06	94	1648±41.41	1605±44.26	97.39
Untreated (Control-II)	01	02	01	04	96	1652±37.74	1619±36.54	98.00

TABLE-25

Nymphal and adult longevity following the application of sublethal concentrations of Acephate on 4th and 5th instar nymphs of *Dysdercus cingulatus*

Concentrations (%) 1µl/nymph	Mean longevity (hrs.) ±S.E.						
	4th instar				5th Instar		
	4th instar	5th instar	Adult male	Adult female	5th instar	Adult male	Adult female
0.002	88.6±7.3	149.2±13.2	594.1±38.7	474.7±32.6	152.9 ± 11.6	626.1±29.5	476.7±15.3
0.001	81.9±6.0	140.6±11.9	560.5±33.9	446.4±29.7	133.1 ± 07.9	569.7±35.8	456.7±10.7
0.0008	77.7±6.9	135.2±10.5	531.8±44.7	425.6±21.8	126.9 ± 13.7	536.7±43.2	436.2±12.3
0.0006	74.6±8.5	129.3±18.3	503.1±40.1	414.3±27.9	120.3 ± 16.5	508.5±39.5	412.3±17.5
0.0004	71.2±9.2	121.7±16.4	488.7±31.3	407.2±36.2	122.1 ± 10.3	494.6±47.2	420.8±09.2
Aceton treated (Control-I)	73.8±7.1	126.4±19.7	479.1±27.7	409.2±27.1	119.6 ± 19.1	470.8±32.9	400.6±18.4
Untreated (Control-II)	71.4±6.4	122.5±10.7	473.7±32.9	413.5±33.8	126.4 ± 14.2	473.0±27.4	404.8±11.9

TABLE-26

Nymphal and adult longevity following the application of sublethal concentrations of ethion on 4th and 5th instar nymphs of *Dysdercus cingulatus*

Concentrations (%) 1µl/nymph	Mean longevity (hrs.) ±S.E.						
	4th instar				5th Instar		
	4th instar	5th instar	Adult male	Adult female	5th instar	Adult male	Adult female
0.006	95.4±8.5	160.8±17.6	621.4±83.7	476.7±42.8	169.8±14.9	655.3±66.3	526.1±55.9
0.004	90.0±9.9	151.8±19.6	569.7±62.6	448.6±49.3	141.7±11.3	599.5±69.2	490.5±50.3
0.002	83.0±10.8	144.1±12.9	546.1±43.6	432.1±56.2	134.4±17.1	549.5±54.1	454.3±61.8
0.001	79.7±7.2	136.5±14.9	508.4±49.1	419.4±37.7	127.6±10.9	506.6±41.7	419.7±47.3
0.0008	74.8±10.5	131.5±15.7	487.3±34.1	406.3±44.7	121.9±13.6	482.9±51.6	411.2±51.4
Solvent treated (Control-I)	77.6±5.4	127.6±9.9	470.8±37.6	400.6±29.7	123.7±9.3	464.8±37.1	402.1±39.3
Untreated (Control-II)	74.3±6.3	131.2±10.2	473.0±39.5	404.8±32.1	121.3±10.8	470.1±31.9	400.9±47.2

TABLE-27

Nymphal and adult longevity following the application of sublethal concentrations of dichlorvos on 4th and 5th instar nymphs of *Dysdercus cingulatus*

Concentrations (%) 1µl/nymph	Mean longevity (hrs.) ±S.E.						
	4th instar				5th Instar		
	4th instar	5th instar	Adult male	Adult female	5th instar	Adult male	Adult female
0.01	98.2±8.8	144.4±16.2	556.8±51.9	452.1±57.3	152.4±17.3	613.7±71.5	478.6±55.1
0.008	90.4±9.9	138.1±12.4	536.0±55.7	431.7±47.2	138.1±15.1	579.6±68.3	454.3±61.9
0.006	83.4±10.7	130.5±14.8	503.5±57.1	421.1±51.7	127.6±11.9	550.4±51.9	437.7±51.4
0.004	79.3±6.4	133.0±11.9	490.9±41.2	411.3±41.9	121.2±13.7	510.3±63.9	417.7±46.2
0.002	81.4±7.9	129.4±13.3	496.3±61.4	405.8±31.2	127.3±10.9	497.7±56.1	407.8±49.8
Solvent treated (Control-I)	77.3±6.3	126.7±10.5	484.2±39.3	407.3±49.5	125.2±12.2	483.3±42.8	409.1±41.3
Untreated (Control-II)	74.4±8.1	123.8±11.2	480.8±43.9	411.2±39.1	122.8±9.7	479.5±39.1	404.1±38.7

TABLE-28

Nymphal and adult longevity following the application of sublethal concentrations of furadan on 4th and 5th instar nymphs of *Dysdercus cingulatus*

Concentrations (%) 1µl/nymph	Mean longevity (hrs.) ±S.E.						
	4th instar				5th Instar		
	4th instar	5th instar	Adult male	Adult female	5th instar	Adult male	Adult female
0.001	75.6±9.2	126.1±14.3	424.4±47.1	387.1±43.7	133.7±11.5	442.3±39.1	355.9±30.9
0.0008	77.9±8.1	129.2±11.9	463.6±51.9	396.3±31.3	128.8±14.9	461.7±31.9	385.8±27.1
0.0006	79.2±8.7	128.2±13.1	481.3±43.5	414.4±37.4	123.4±10.3	468.1±37.0	391.6±35.7
0.0004	82.7±8.0	132.2±10.5	498.3±56.4	419.7±44.1	119.6±12.1	482.2±41.7	387.5±31.8
0.0002	78.7±7.3	135.9±12.7	491.4±50.2	423.2±47.2	116.2±10.9	471.3±44.0	402.2±44.0
Solvent treated (Control-I)	81.4±7.6	134.2±10.4	493.5±40.7	421.6±33.8	120.4±11.3	475.1±37.1	403.5±33.1
Untreated (Control-II)	78.3±6.8	129.7±11.2	497.1±43.2	423.4±29.2	123.3±10.6	469.8±33.5	406.3±29.9

TABLE-29

Nymphal and adult longevity following the application of sublethal concentrations of carbaryl on 4th and 5th instar nymphs of *Dysdercus cingulatus*

Concentrations (%) 1µl/nymph	Mean longevity (hrs.) ±S.E.						
	4th instar				5th Instar		
	4th instar	5th instar	Adult male	Adult female	5th instar	Adult male	Adult female
0.0025	82.3±8.9	142.9±11.6	448.6±39.1	405.6±44.1	150.9±17.3	584.9±47.7	471.7±40.2
0.002	79.3±8.1	138.1±09.3	471.3±33.6	409.3±47.8	147.9±13.9	546.5±51.8	443.2±37.6
0.0015	76.8±7.3	133.9±13.9	474.2±41.3	420.9±39.2	136.2±11.1	503.4±41.3	421.9±31.9
0.001	71.2±6.6	136.9±15.1	487.7±30.9	411.7±40.1	131.4±13.7	488.0±39.2	411.9±37.7
0.0008	74.9±5.2	130.7±10.7	492.5±39.2	416.2±33.5	127.9±10.9	476.9±40.4	413.843.8
Solvent treated (Control-I)	75.5±6.3	132.4±09.7	482.4±35.7	413.9±31.9	129.7±09.9	479.4±37.1	406.6±38.9
Untreated (Control-II)	80.2±8.2	134.7±7.1	479.9±30.1	416.5±37.6	127.1±10.7	472.3±36.3	411.8±33.2

TABLE-30

Nymphal and adult longevity following the application of sublethal concentrations of aminocarb on 4th and 5th instar nymphs of *Dysdercus cingulatus*

Concentrations (%) 1µl/nymph	Mean longevity (hrs.) ±S.E.						
	4th instar				5th Instar		
	4th instar	5th instar	Adult male	Adult female	5th instar	Adult male	Adult female
0.004	95.7±10.2	159.1±13.9	540.9±38.3	465.9±40.9	151.3±10.6	601.7±51.3	482.2±41.7
0.002	91.5±09.5	152.3±11.7	518.5±41.7	457.3±37.1	143.4±13.2	553.8±59.7	451.6±39.2
0.001	86.5±09.1	144.6±14.2	505.3±31.2	443.4±33.1	133.4±09.9	516.2±49.1	423.1±44.9
0.0008	84.6±08.7	139.4±10.7	493.6±29.8	428.3±47.2	126.1±14.1	491.4±37.9	408.6±38.6
0.0006	80.7±08.8	141.4±12.4	498.9±35.7	420.9±30.3	127.7±09.3	478.9±32.9	397.3±31.8
Solvent treated (Control-I)	83.2±07.0	137.2±09.1	487.3±30.1	421.1±29.9	122.4±07.7	469.3±37.6	401.8±30.1
Untreated (Control-II)	84.7±06.6	131.8±10.6	483.6±33.9	418.4±29.9	124.6±08.7	474.1±30.2	410.9±34.4

TABLE:31

Larval, pupal and adult longevity following the application of sublethal concentrations of Acephate on 5th and 6th instar larvae of *Diacrisia obliqua.*

Concentrations (%) 2µl/ larva	Mean longevity (hrs) ± S.E.								
	5th instar					6th Instar			
	5th instar	6th instar	Pupal stage	Adult male	Adult female	6th instar	Pupal stage	Adult male	Adult female
0.1	108.9±09.3	148.9±11.3	306.8±29.1	430.8±39.6	217.3±20.7	144.6±12.3	298.5±27.1	508.1±43.3	268.1±21.7
0.08	098.1±09.1	138.7±12.1	270.8±21.8	405.5±42.5	205.9±17.8	138.5±11.9	271.6±31.3	475.7±40.1	251.5±19.8
0.06	092.3±10.7	136.2±10.7	258.2±20.9	383.7±37.1	200.2±19.1	129.1±14.0	256.9±25.8	439.4±37.1	253.3±23.2
0.04	087.6±08.3	131.2±08.5	244.3±17.3	376.5±31.9	194.5±15.3	130.8±09.7	250.3±23.1	415.2±36.9	242.2±27.3
0.02	086.4±09.1	133.5±08.1	249.1±19.2	372.4±33.5	196.4±13.9	129.6±10.5	253.0±20.7	419.6±41.8	240.4±20.1
Aceton treated (Control-I)	083.2±07.2	127.3±09.3	239.7±15.7	362.1±29.6	190.7±11.4	127.1±09.1	244.7±19.3	403.2±32.1	237.3±18.7
Untreated (Control-II)	080.4±07.0	129.7±10.7	241.5±13.1	367.2±27.1	187.2±12.5	129.4±09.6	247.1±20.6	411.5±30.7	231.2±17.9

TABLE: 32

Larval, pupal and adult longevity following the application of sublethal concentrations of ethion on 5th and 6th instar larvae of *Diacrisia obliqua.*

Concentrations (%) 2µl/ larva	Mean longevity (hrs) S.E.								
	5th instar					6th Instar			
	5th instar	6th instar	Pupal stage	Adult male	Adult female	6th instar	Pupal stage	Adult male	Adult female
0.6	99.8±9.1	160.5±13.9	291.9±22.7	405.9±34.7	217.7±17.5	135.2±11.7	298.6±23.3	482.4±42.8	267.7±21.2
0.4	93.7±8.2	151.0±15.7	281.7±26.2	401.1±38.7	209.9±21.9	126.8±13.9	278.1±29.5	457.0±37.3	258.1±22.1
0.2	90.4±8.8	141.5±11.3	268.3±19.7	386.2±30.3	202.0±15.3	122.1±15.1	265.3±21.5	440.3±32.1	252.4±19.0
0.1	87.8±7.0	140.1±10.9	263.7±21.4	378.8±29.1	204.0±19.4	123.4±10.5	257.9±19.9	429.8±29.8	254.6±17.7
0.08	88.3±6.3	139.3±12.6	266.1±27.3	382.5±25.5	201.4±18.3	121.9±10.2	259.3±20.3	432.9±22.9	248.8±20.1
Solvent treated (Control-I)	86.1±5.2	136.1±09.7	256.2±17.1	371.4±21.3	196.2±11.4	119.7±08.3	253.1±17.2	423.2±19.8	245.3±15.5
Untreated (Control-II)	84.5±4.9	137.2±08.1	259.1±16.7	376.1±19.7	202.1±13.7	124.3±09.7	250.7±12.4	428.4±17.2	255.1±13.3

TABLE: 33

Larval, pupal and adult longevity following the application of sublethal concentrations of dichlorvos on 5th and 6th instar larvae of *Diacrisia obliqua*.

Concentrations (%) 2µl/ larva	Mean longevity (hrs) ± S.E.								
	5th instar					6th Instar			
	5th instar	6th instar	Pupal stage	Adult male	Adult female	6th instar	Pupal stage	Adult male	Adult female
0.4	94.9±8.3	137.9±11.7	342.3±37.4	458.7±47.1	241.1±21.8	146.9±16.3	276.2±25.5	444.7±40.6	234.3±27.1
0.2	90.1±7.1	134.2±13.2	320.0±31.9	431.0±44.6	236.6±19.6	139.0±13.9	266.8±21.9	429.0±37.2	219.6±20.6
0.1	85.3±9.7	129.2±10.1	297.7±35.1	419.2±33.1	227.8±17.5	140.7±15.2	260.4±23.7	413.7±31.9	223.8±23.8
0.08	82.9±6.9	126.7±11.9	289.4±23.9	423.1±37.9	230.0±20.9	136.9±11.7	261.2±19.8	395.0±36.4	215.1±21.9
0.06	83.7±7.1	128.0±14.3	283.8±20.8	407.3±27.4	225.6±26.7	135.1±10.8	257.1±20.5	393.0±31.3	213.8±16.4
Solvent treated (Control-I)	79.8±5.2	124.3±09.0	278.3±15.5	395.5±23.7	221.2±19.9	132.4±09.4	253.4±17.2	383.1±27.7	209.2±17.1
Untreated (Control-II)	82.1±4.9	131.2±08.7	271.2±14.4	399.1±20.7	215.8±17.6	135.3±10.2	259.1±15.9	395.5±25.7	213.1±15.6

TABLE: 34

Larval, pupal and adult longevity following the application of sublethal concentrations of furadan on 5th and 6th instar larvae of *Diacrisia obliqua*.

Concentrations (%) 2µl/ larva	Mean longevity (hrs) ± S.E.								
	5th instar					6th Instar			
	5th instar	6th instar	Pupal stage	Adult male	Adult female	6th instar	Pupal stage	Adult male	Adult female
0.08	95.0±9.7	157.8±17.3	325.1±29.6	486.6±40.7	234.9±25.8	143.7±13.9	305.1±27.5	473.3±40.6	246.7±27.1
0.06	91.5±8.2	149.5±14.3	301.7±31.1	457.7±45.1	224.2±19.7	140.6±11.6	292.0±21.0	460.1±35.9	233.4±20.3
0.04	88.9±9.9	145.4±15.1	278.3±26.8	437.1±39.2	217.8±17.9	142.2±10.3	276.2±25.8	451.6±29.7	228.0±11.3
0.02	90.6±7.3	144.0±11.7	273.1±23.3	424.7±27.1	220.0±13.5	135.1±09.7	270.4±19.1	444.2±31.9	229.7±13.0
0.01	90.2±7.7	141.2±09.5	265.3±27.9	428.8±29.9	216.5±18.9	134.4±10.3	267.5±17.2	447.7±26.3	225.8±17.1
Solvent treated (Control-I)	87.2±6.2	138.5±08.8	260.1±15.7	412.4±34.6	213.6±11.7	138.2±08.8	263.1±12.4	434.3±23.1	222.3±11.3
Untreated (Control-II)	89.1±5.8	143.2±09.1	255.4±14.2	421.2±28.5	209.3±12.9	131.7±10.1	261.8±15.2	439.5±25.9	215.4±10.0

TABLE: 35

Larval, pupal and adult longevity following the application of sublethal concentrations of carbaryl on 5th and 6th instar larvae of *Diacrisia obliqua*.

Concentrations (%) 2µl/ larva	Mean longevity (hrs) ± S.E.								
	5th instar					6th Instar			
	5th instar	6th instar	Pupal stage	Adult male	Adult female	6th instar	Pupal stage	Adult male	Adult female
0.15	118.4±16.3	169.1±20.5	292.6±25.8	416.5±33.6	226.5±17.4	137.7±16.2	339.4±30.9	582.0±42.7	250.8±31.0
0.1	110.6±13.1	160.3±15.9	275.6±20.4	394.6±39.2	218.3±14.1	127.4±13.8	301.7±27.6	527.9±50.9	224.8±25.6
0.08	103.8±17.4	155.9±17.2	264.1±23.9	380.0±44.7	212.2±23.8	128.9±09.4	290.9±23.0	500.8±41.4	218.5±19.7
0.06	100.2±09.5	151.0±10.0	256.5±17.1	371.7±28.2	208.1±16.7	125.3±07.1	276.6±19.3	473.7±27.7	213.2±13.9
0.04	100.6±11.0	152.3±09.1	253.9±13.9	376.1±22.4	230.6±15.9	124.1±14.3	278.2±25.7	459.3±26.1	215.5±17.7
Solvent treated (Control-I)	097.1±08.1	147.1±07.0	243.9±10.0	365.4±17.3	204.1±13.3	122.5±18.1	269.4±13.6	451.2±20.9	210.1±11.0
Untreated (Control-II)	094.5±07.3	151.2±08.8	240.8±12.4	372.6±14.5	199.7±11.1	125.3±10.2	273.1±17.9	446.1±23.8	215.3±14.3

TABLE: 36

Larval, pupal and adult longevity following the application of sublethal concentrations of aminocarb on 5th and 6th instar larvae of *Diacrisia obliqua*.

Concentrations (%) 2µl/larva	Mean longevity (hrs) ± S.E.								
	5th instar					6th Instar			
	5th instar	6th instar	Pupal stage	Adult male	Adult female	6th instar	Pupal stage	Adult male	Adult female
0.25	105.7±12.4	168.5±21.9	299.2±27.3	423.4±35.4	231.3±20.7	163.1±13.7	374.5±33.5	535.1±47.1	218.9±17.6
0.2	101.0±10.7	158.5±18.4	284.3±16.9	412.0±39.2	222.7±17.5	151.7±19.4	340.9±30.1	491.3±53.3	205.6±13.9
0.15	097.2±13.1	152.7±13.2	269.5±19.9	400.8±44.4	216.4±25.0	145.1±12.1	312.7±19.8	457.4±49.0	194.3±21.0
0.1	095.5±09.3	147.0±10.8	257.1±21.8	389.3±30.9	213.8±19.0	137.3±16.6	290.1±26.0	424.2±40.4	197.2±15.7
0.08	096.5±10.9	145.1±07.7	252.7±19.3	392.9±35.2	215.7±13.1	134.7±09.9	279.5±22.4	426.7±32.9	193.4±10.4
Solvent treated (Control-I)	093.6±07.1	142.8±09.2	247.3±15.6	381.5±28.4	210.1±16.6	130.8±07.2	271.4±15.5	411.8±29.1	190.4±09.3
Untreated (Control-II)	099.2±08.4	137.1±08.4	249.5±11.8	387.2±31.3	207.3±11.9	133.9±10.8	278.1±13.5	416.5±33.7	196.2±08.9

13. Anatomical and Histological Observations on The Gonads of *Dysdercus cingulatus* Fabr. (Hemiptera: Pyrrhocoridae)

13.1. Male reproductive organs

The male reproductive organs of *D. cingulatus* consists of a pair of testes (Tes), two vasa deferentia (Vd) and a single ejaculatory duct (Ej) with an end dilated into a kidney shaped bulbus ejaculatorius (Be). There is a pair of accessory glands called mesadene glands (Md) (Plate-II, Fig.D).

Each testis is red in colour, ovoid in shape, lying ventrolaterally in the fifth and sixth abdominal segments and consists of seven testicular follicles (Tes.fol.) enclosed within a common membranous sheath i.e. tunica which is pigmented and hence the testes appear red. Each testicular follicle is spindle shaped with a blind anterior end and posteriorly it opens into a seminal vesicle through a short and narrow duct, the vas efferens (Ve). The wall of the testicular follicle is made up of an epithelium of flattened cells with elliptical nuclei which have bright chromatin granules. The interior of each testicular follicle contains a number of cysts in various stages of development. The anterior region of the follicle is the germarium (Gr), packed with germ cells. The cells are small and round with a distinct nucleus in each. Behind the germarium, there is a region of spermatogonia (Sg) which is followed by an area of spermatocytes (Sps). The spermatogonia and spermatocytes are in active state of differentiation and various stages of mitotic divisions are evident in these regions. Posterior to the region of spermatocytes, there are cysts containing secondary spermatocytes and spermatids (St.). Each spermatid has a clearly visible nucleus and a nebenkern. Finally there is a zone of freely swimming spermatozoa (Spz). Between the cysts there are nutritive cells or the trophocytes (Tc) which are sparsely distributed. However, their number is progressively higher in the region containing spermatids. A small number of trophocytes also occur among the fully differentiated spermatozoa. Some trophocytes are also traceable between the testicular wall and the tunica surrounding it.

13.2. Female reproductive organs

The female reproductive organs of *Dysdercus cingulatus* consist of a pair of ovaries (Ov), lateral oviducts (Lo), a single but relatively short common oviduct (Co) and a spermatheca (Sm), opening in the dorsal wall of the common oviduct. There is also a pair of bright yellow coloured accessory glands (AcGl), each opening on either side of the bursa copulatrix (bc). Each accessory gland consists of numerous short and branched tubules (Plate-II, Fig. A).

Each ovary is milky white in colour and lies ventro-laterally in the posterior part of the abdomen on either side of the digestive tract. In each ovary, there are seven ovarioles which open into the lateral oviduct. Each ovariole has four distinct parts. Anteriorly there is a terminal filament which is followed by a germarium. The greater part of the ovariole is occupied by the vitellarium containing developing oocytes. Finally, each ovariole has a tubular pedicel which opens into the lateral oviduct. In the mature female, the size of ovarioles is much increased and each has generally 8-10 ova before the commencement of the oviposition of the first batch of the eggs (Plate-II, Fig. B).

Further, each ovariole is entirely surrounded by two cellular sheaths from the tip of the terminal filament to the pedicel. The outer epithelial sheath has elliptical nuclei. It is sometimes very difficult to identify this sheath and the only indication of its presence being the nuclei which are situated far apart. The inner sheath has ovoid nuclei and it is best seen around the vitellarium where it invests the outer interfollicular cells and around the corpus luteum after the discharge of the eggs (Plate-II, Fig. C).

The terminal filament is separated from the apical part of the germarium by a basal transverse septum. Both oogonia and trophocytes arise from the same type of cells in the germarium and in early stages these can not be distinguished. In the advanced stage of differentiation each trophocyte has a very large granular nucleus surrounded by a small amount of cytoplasm. In the middle zone of germarium, the trophocytes fuse to form binucleate and multinucleate cells which lie nearer to the

trophic core i.e. a cytoplasmic core in the center of the germarium. In the multinucleated cells the nuclear material is in various stages of disintegration and this state is most often seen in the posterior part of the germarium.

Posterior to the trophocytes there is a prefollicular tissue in the form of a solid mass of cells. The older prefollicular cells grade posteriorly into multilayered columnar epithelium enclosing a young oocyte. In the anterior part of the vitellarium, the follicles have two or more layered epithelium. Progressively, the multilayered follicular epithelium posteriorly becomes single layered with columnar cells. In more developed condition the epithelial cells become cuboidal and finally squamous with distinct intercellular space around each fully mature egg. In the vitallarium the follicles are arranged in linear succession but separated from each other by interfollicular plug which is at first several layered thick but in advanced vitellogenesis it is reduced to two or three layers of flattened cells. Similar plug also exists between the last follicle and the pedicel (Plate-II, Fig. F).

Young oocytes are found at the base of the germarium and they are almost similar in size to multinucleate trophocytes but can be distinguished from them in having large amounts of cytoplasm with one spherical nucleus. The oocytes in the neck region of the vitellarium are small and elliptical or sometimes spherical and spindle shaped. The older oocytes gradually become ovoid and spherical. The ooplasm of the young oocytes is homogeneously granular both at the base of the germarium and in the previtellarium. When the oocytes are about to mature and surrounded by a single layer of cuboidal epithelium, the yolk spheres appear at the oocyte periphery and later entire oocyte is packed with such spheres. The chorion is not laid down until after the yolk deposition has been completed. The nucleus of the young oocyte in the germarium is spherical and centrally located with dense chromatin. Progressively, the nucleus develops into a germarial vesicle with an accumulation of vesicular fluid which allows the vesicle to increase in size. The germinal vesicle is displaced to one side at the start of vitellogenesis and stays at this position throughout the yolk production.

Each developing oocyte has a nutritive cords connecting it to the base of the trophic core. It penetrates the layer of pre-follicular and interfollicular masses. The cytoplasm of the nutritive cord is fibrillar. As the vitelline membrane is formed around the oocyte after the completion of yolk deposition, the attachment of this cord is broken off.

After ovulation the follicular epithelium of empty follicles disintegrates and contracts to form the corpus luteum. The cellular boundaries of the ruptured follicle gradually disappear and the nuclei disintegrate. Later the nuclei undergo pycnosis and the chromatin masses fuse to form large clumps (Plate-II, Fig. C).

The pedicel is the small tube which connects the vitellarium posteriorly with lateral oviduct. The wall of pedicel consists of a layer of squamous cells whose nuclei are ovoid and small in comparison with those of the follicular epithelium.

14. Effects of Insecticides on The Testes of Adult Males Following Topical Application on Nymphal and Larval Stages of *Dysdercus cingulatus* and *Diacrisia obliqua*:

The topical application of sublethal concentration of any of the selected organophosphate and carbamate insecticides on both the 4th and 5th instar nymphs of *D. cingulatus* and 5th and 6th instar larvae of *D. obliqua* did not cause any marked effect on the anatomical and histological structure of the testes. In case of *D. cingulatus*, the size of the testes was unchanged even after 15 days. The cellular structure of the testes also remain unchanged (Plate-III, Fig. D-I). Similarly, in case of *D. obliqua*, the size as well as the cellular organization of the male reproductive system remained normal (Plate-XIII, Fig. A-F), except in some adults which emerged from the 6th instar larvae treated with higher concentrations of furadan. In these adults, the two testes could not get fused completely and remained separate (Plate-XII, Fig.). In histological observations, the spermatogonia, spermatocytes, spermatids, and spermatozoa in *Diacrisia obliqua* (Plate-XIII, Fig. G & H) as well as in *Dysdercus cingulatus* were almost intact and there was no damage at any level. Further, the density of these was unchanged and more than half of each testicular follicles were packed with fully mature spermatozoa. The density of the later was also unaffected in vas diference. The spermathecae of the affected females mated with affected males also revealed normal transfer of sperms. The motility of the spermatozoa was also unaffected.

15.1. Effects on The Ovaries of Adult Females Following Topical Application of Acephate on 4th Instar Nymphs of *Dysdercus cingulatus Fabr.*

15.1.1. After One Day

The ovaries of one day old affected females emerged from the 4th instar nymphs which were treated with different concentrations of acephate did not show any change in their anatomical and histological structures as compared with that of the control females of the corresponding age.

15.1.2. After Five Days

The females which emerged from the treated nymphs of 4th instar developed some anatomical changes. With respect to the application of the higher concentrations of acephate (0.002, 0.001 and 0.0008%) on the nymphs, the ovarioles at this age became less pronounced in size as compared to that of the untreated females. Further, there was inhibition in the development, descent and maturation of young oocytes in the vitellarium and generally not more than 7 oocytes were present in each ovariole compared with 8 to 10 in that of untreated females (control) of the corresponding age. In some severely affected ovaries, the number of oocytes per ovariole were not more 3-4 (Plate-IV, Fig. H). The ovarioles of the affected females had clumping of chromatin in the prefollicular tissue leading to decimation of the tissue. Some of the oocytes in the prefollicular region could not descend properly into the previtellarium and a few of them got the beginning of the abnormal development inside the germarium. Generally, the remaining oocytes which reached the previtellarium were grouped in pairs in each egg chamber. Thus compound egg chambers were formed in the previtallarium and the oocytes of a compound egg chamber were surrounded by a common follicular epithelium. In the normal females the prefollicular cell reserves remain sufficient to envelop each newly descended oocyte in the vitellarium even in very old females. Further, between the older oocytes of the vitellarium the interfollicular cells did not form inter

follicular plug like that of the normal ovarioles. Instead there was a single layer of cells forming a thin septum between the adjacent chamber (Plate-IV, Fig.C). In addition, there was clumping of chromatin in some of the follicular cells. The younger oocytes had homogeneously granular cytoplasm, whereas, in the older oocytes the ooplasm was vacuolized (Plate-IV, Fig. E). In some severely affected ovaries (0.002%), most of the oocytes in the vitellarium had spares yolk deposition and were highly vacuolated (Plate-X, Fig. B). The process of degeneration of the oocytes commenced with the appearance of vacuoles inside the oocytes and finally the cells collapsed and their cell debris were either resorbed by the ovarian wall or passed down in the oviduct (Plate-X, Fig. A). However, the application of the lower concentrations (0.0006% and 0.0004%) of acephate did not show any adverse effect on the anatomy and histology of the ovaries.

15.1.3. After Ten Days

The females, which emerged from the 4th instar treated nymphs, when became ten days old, showed some anatomical abnormalities in their ovaries. With the application of higher concentrations of acephate (0.002, 0.001 and 0.0008%), the size of the ovaries reduced remarkably as compared to normal ovaries. Although, the germarium and vitellarium were distinguishable, the egg chambers in the vitellareal part were smaller in size and less in number as compared to control of the corresponding age (Plate-IV, Fig. J). In some severely affected ovaries, the ovarioles showed resorption of the oocytes which had descended into the vitellarium (Plate-IV, Fig. G). However, with respect to the application of the lower concentrations (0.0006 and 0.0004%), no abnormalities were seen in the anatomical structure of the ovaries.

Histologically, some abnormalities were observed in the germarium of the ovarioles of the females that emerged from the nymphs treated with higher concentrations of acephate. Although most of the anterior portion of the germarium was quite intact like normal germarium having normal trophocytes, in its posterior region the trophocytes had clumped chromatin. In some cases, the trophic core as well as the nutritive cords were also absent. Owing to the degeneration of

trophocytes as well as trophic core, some empty spaces appeared in the posterior region of the germarium (Plate-IV, Fig. D). Some of the oocytes in the vitellarium showed different stages of degeneration and resorption. The disintegration of these oocytes of the vitellarium was in random order and the process of degeneration commenced with appearance of vacuoles inside the oocytes and finally the cells collapsed (Plate-IV, Fig. B). In some severely affected ovarioles the oocytes in the vitellarium were smaller in size in comparision with control and some of them were in acute state of disintegration (Plate-IV, Fig. F). There was no trace of the vitelline membrane or chorion around some of the older oocytes. However, following the application of the lower concentrations (0.0006 and 0.0004%) on the nymphs no damage occurred in the ovaries of emerged females of this age.

15.1.4. After Twenty Days

In the females, after 20 days following emergence from the treated 4th instar nymphs, there was no significant advancement of damage in anatomical or histological structure of the ovaries, and these were almost like those of ten days old affected females. The same changes continued till death of the affected females and no recovery in the ovaries of such females was observed.

15.2. Effects on Ovaries of Adult Females Following Topical Application of Acephate on 5th Instar Nymphs of *Dysdercus cingulatus* Fabr.

15.2.1. After One Day

The ovaries of one day old affected females had no changes in their anatomical and histological structure when compared with the ovaries of the control females of the corresponding age.

15.2.2. After Five Days

The ovaries of the 5 day old females which emerged from the 5th instar nymphs treated with 0.002 and 0.001% acephate developed some anatomical abnormalities in their ovarioles. In both cases, the development of ovarioles was inhibited significantly and there was reduction in their size. Furthermore, generally the number of mature oocytes in the vitellarium reduced to 6-8 per ovariole as compared to 8-10 in case of control females. In certain severely affected ovaries, the number of mature oocytes per ovariole reduced to 2-3 (Plate-IV, Fig. I). In certain ovaries the oocytes was not matured in the vitellarium. In few ovarioles the oocytes started degeneration and there was a darkly stained cellular mass ar the end of the ovarioles (Plate-X, Fig. F). However, the females affected by lower concentrations of acephate (viz., 0.0008, 0.0006, and 0.0004%) had normal ovaries with respect to their size. The maturation of the young oocytes in the vitellarium was like those of control females of the corresponding age.

The ovarioles of these females developed some histological anomalies. The cellular organization of the germarium lost its originality and the trophocytes of the anterior region showed clumping of chromatin in their nuclei. In some cases the trophic core as well as the nutritive cords were not intact and became fragile. The density of the prefollicular cells was also less and some oocytes were retained in the germarium. Most of the space of the germarium in the posterior region was occupied by such oocytes and they pushed the trophocytes along with the clumped chromatin towards the anterior part of the germarium. The development and the maturation of the oocytes in the vitellarium was also abnormal. In few oocytes, the ooplasm was not homogeneously granular and the deposition of yolk was very less (Plate-IV, Fig. A). Some young oocytes present in the germarium as well as vitellarium had some small size vacuoles. In certain severely affected ovaries, the oocytes in the vitellarium showed different stages of degeneration and resorption (Plate-IV, Fig. K). However, the follicular plug of the pedicel was intact like those of normal ovary. Whereas the cellular structure of the ovary of the females emerged from the nymphs following application of the lower concentration of acephate (0.0008, 0.0006 and 0.0004%) was like that of the control females of the same age.

15.2.3. After Ten Days

After ten days, the ovaries of the emerged females from the nymphs following the topical application of higher concentrations (0.002 and 0.001%) of acephate showed some changes in both anatomical as well as histological structures. Anatomically, the ovaries of the affected females were smaller in size, although the germarium and the vitellarium were distinguishable. The egg chambers were also smaller, whereas, the lateral oviducts were quite longer than those of the normal females. However, following the topical application of the lower concentrations (0.0008, 0.0006 and 0.0004%) of acephate, the emerged females of this age had normal ovaries.

The ovarioles of these females affected with higher concentrations of acephate, histologically, developed some anomalies. Although the shape and size of the germarium was normal, its cellular structure was changed in the posterior half where some of the trophocytes showed clumping of chromatin in their nuclei. The oocytes were irregular in shape although some of them were under different stages of maturation. The vitellarial part of the ovarioles squeezed slightly and it became short. The ooplasm of the oocytes in the vitellarium was homogeneously granular but in some oocytes it indicated the commencement of vacuolization. The interfollicular plugs, follicular plug of the pedicel and follicular epithelium were normal. The nutritive cords were also intact but in some cases these were quite fragile. The cellular organization of the ovarioles in the females of this age, which emerged from the nymphs treated with lower concentrations of acephate was unchanged.

15.2.4. After Twenty Days

The ovaries of the twenty day old females, which emerged following the application of the aforesaid concentrations of acephate on the 5th instar nymphs were without much difference in the anatomical as well as histological structures as compared to that of 10 day old affected females. The damage was almost similar,

however, in a few ovarioles there was some recovery. In ceratin severely affected ovaries the oocytes in the vitellarium of few ovarioles were mostly elongated in which occassionally vitellogenesis was completed and the chorion was also secreted around them. Whereas in some other ovarioles of the same ovary, the oocytes were degenerated and resorbed (Plate-IV, Fig. L).

16.1. Effects on The Ovaries of Adult Females Following Topical Application of Ethion on 4th Instar Nymphs of *Dysdercus cingulatus* Fabr.

16.1.1. After One Day

The ovaries of one day old females emerged from the survived treated 4th instar nymphs following the topical application of 0.006, 0.004, 0.002, 0.001 and 0.0008% ethion were like those of control female of the corresponding age. Both their germarium and vitellarium were clearly differentiated from each other and the number of oocytes in the vitellarium was also same as in the control females. The histological organization of these ovaries was also normal and similar to that of the control.

16.1.2. After Five Days

After 5 days following emergence the ovaries of the affected females did not show much damage or resorption of the oocytes. However, the females affected with higher concentrations (i.e. 0.006 and 0.004%) of this chemical developed remarkably smaller ovaries. The number of oocytes reduced to 6-8 in each ovariole as compared to 8-10 in normal females. These oocytes were not arranged linearly (Plate-V, Fig. F). The germarium was intact. In some severely affected ovaries (0.006%), the oocytes in the vitellarium were not matured and started degeneration. The debris of these degenerated oocytes were accumulated at the base of the ovarioles (Plate-X, Fig. D). The females affected with application of the lower

sublethal concentrations (i.e. 0.002, 0.001 and 0.0008%) of ethion had normal ovaries.

The ovaries of the affected females, with respect to the higher concentrations (i.e. 0.006 and 0.004%) on the nymphs, developed some remarkable changes in the cellular structures. Although, the shape and size of the germarium was normal, some trophocytes in its posterior region showed clumping of the chromatin in their nuclei. The trophic core throughout the germarium was intact except in a few cases where it started disintegration. Further, the density of prefollicular cells was also less at these places and occasionally two or more oocytes were fused together to form a compound oocyte which had more than one germinal vesicles. However, the ooplasm of these oocytes was homogeneously granular and also uniform. Most of the oocytes in the vitellarium were normal but they had comparatively slow vitellogenesis. The interfollicular plugs became slightly thin, whereas, the follicular plug of the pedicel was intact and consisted of several layers of follicular cells as in the ovarioles of the untreated (control) females. On the other hand, the topical application of the lower concentrations (0.002, 0.001 and 0.0008%) on the nymphs did not cause any damage to the cellular organization of the ovaries.

16.1.3. After Ten Days

The anatomical structures of the ovaries of ten day old females which emerged from the treated 4th instar nymphs following the topical application of the higher concentrations of this chemical showed some abnormalities as compared to the control females of the corresponding age. Anatomically the size of the ovaries of the affected females was smaller than that of the control females of the corresponding age. In rare (one or two) cases the germarium and the vitellarium were not clear. The number of oocytes in the vitellarium was smaller as compared to control females and the lateral oviducts were proportionally longer (Plate-V, Fig. G). Further, some of the oocytes started showing disintegration and resorption. Thus, clear and transparent spaces were formed at some places in the vitellarium (Plate-V, Fig. E). Whereas the application of the lower sublethal concentrations of ethion

(0.002, 0.001 and 0.0008%) on the same instar could not affect the ovaries of the affected females up to the present age.

The histological picture of the ovaries of ten day old females, after the application of the higher concentrations (0.006 and 0.004%) of this chemical on the nymphs was appreciably damaged. The cellular organization of nearly one fourth of the posterior region of the germarium was lost completely (Plate-V, Fig. D). The trophocytes of these areas showed clumping of chromatin. In the vitellarium, commencement of disintegration of oocytes took place and resorption followed in random order. The follicular epithelium of the vitellarium became slightly thin. However, the interfollicular plugs of the vitellarium and the follicular plug of the pedicel were intact like those of the normal ovary. Whereas the topical application of the lower concentrations of ethion on the nymphs did not adversely affect the cellular structure of the ovaries of these 10 days old affected females.

16.1.4. After Twenty Days

The ovaries of the affected females after 20 days following emergence showed some recovery of the damage as caused by the higher concentrations in comparison to 10 day old females. Although, the size of the ovaries of the affected females was still smaller, the discrimination between the germarium and the vitellarium was clear. The number of oocytes per ovariole was generally 6-8, and there was no change in the size of the lateral oviducts. In some cases, few matured eggs were retained in the ovariole (Plate-V, Fig. J).

The cellular structure of the germarium was intact except at a few places where the trophocytes showed mild clumping of chromatin in their nuclei. The trophic core in the germarium was intact. The oocytes in the vitellarial region had normal vitellogenesis except in some cases where it was slowed down and some vacuoles were present. The interfollicular plugs and the follicular plug of the pedicel were distinct and normal. However, with respect to the topical application of the lower concentrations (i.e. 0.002, 0.001 and 0.0008%) of ethion the cellular nature of the ovaries remained similar to the ovaries of the control females of this age.

16.2. Effects on Ovaries of Adult Females Following Topical Application of Ethion on 5th Instar Nymphs of *Dysdercus cingulatus* Fabr.

16.2.1. After One Day

There was no anatomical disorder or histological damage in the ovaries of the one day old females emerged from the treated nymphs by the aforesaid concentrations of this chemical.

16.2.2. After Five Days

The ovaries of the five day old females were generally normal. However, the topical application of the strongest concentration (0.006%) of ethion on the nymphs caused minor disorder in the anatomical structure of the ovaries. Generally the size of the ovaries reduced slightly and the number of oocytes in the ovarioles varied from 6-8. In some more severely affected ovarioles, there were only 2-3 oocytes in each ovariole. These oocytes were not arranged linearly (Plate-V, Fig. H). Whereas with respect to the topical application of the remaining concentrations, the ethion did not induce any anomaly in the anatomical structure of the affected females and these were similar to the control females.

The histological picture of the ovarioles of these females revealed some changes with respect to the strongest concentration (0.006%) of ethion. The internal structure of the germarium in posterior region was slightly affected by the clumping of the trophocytes. In some places the trophic core was absent. In the lower half of the germarium, some oocytes were irregular in shape though these were under different stages of maturation. The oocytes in the vitellarium had normal vitellogenesis except in a few cases where it was slow and some vacuoles were present in these oocytes (Plate-V, Fig. C). There was no change in the interfollicular plugs and the follicular plug of the pedicel. Whereas the topical application of the

remaining concentrations of ethion did not produce any destruction in the cellular structure of the ovaries.

16.2.3. After Ten Days

After ten days also, the ovaries of the emerged affected females did not show any change except the reduced size than those of the control females of the similar age. (Plate-V, fig. I).

The histological organization of these ovaries also did not reveal any marked damage except in germarium where occasional clumping of chromatin in the prefollicular cells was observed.

16.2.4. After Twenty Days

The ovaries of 20 days old affected females did not show much difference in anatomical structure as compared to that of the 10 days old affected females.

The histological damage in these ovaries was almost similar to that of ten day old females where, mild damages were recorded in the localized tissue of the germarium. The rest of the cellular structures of the germarium and vitellarium remained like those of normal.

17.1. Effects on The Ovaries of Adult Females Following Topical Application of Dichlorvos on 4th Instar Nymphs of *Dysdercus cingulatus* Fabr.

17.1.1. After One Day

After one day, the ovaries of the affected females, emerged from the survived treated nymphs did not show any difference both anatomically and histologically in comparison to the control females, irrespective of the concentrations of this chemical. The germarium and the vitellarium were clearly differentiated from each other. All the oocytes in the vitellarium were intact and there was no sign of disintegration or resorption of the oocytes. The histological organization of ovarioles was also like that of normal.

17.1.2. After Five Days

The ovaries of the five days old females which emerged from the treated 4th instar nymphs also showed no changes in the anatomical structure. In their ovarioles both the germarium and the vitellarium were very clearly distinguishable from each other and all the oocytes in the vitellarium were intact. However, the size of the ovaries and number of oocytes in the vitellarium were generally reduced from 8-10 to 7-9, whereas, in some more severely affected ovaries, the number of oocytes in the vitellarium were reduced to 4-5 (Plate-VI, Fig. F). The size of the lateral oviducts was enlarged slightly in case of females that emerged from nymphs treated with 0.01% dichlorvos.

The cellular structure of the germarium was generally normal except the posterior half of some ovarioles where a few prefollicular cells as well as the trophocytes which surround the trophic core had clumping of the chromatin(Plate-VI, Fig. C). There was normal descent of the oocytes from the germarium except in some of the ovarioles which had retention of the oocytes within the germarium or occurrence of abnormal descent of younger oocytes into the neck of the vitellarium.

Most of the oocytes in the vitallarium were quite normal but a few of them had vacuolization (Plate-VI, Fig. D), the interfollicular plugs of the vitellarium as well as follicular plug of the pedicel were quite normal.

17.1.3. After Ten Days

During the next five days, the anatomical structure of the ovaries of affected females remain unchanged, whereas, the size of the ovarioles reduced noticeably. The number of oocytes in some more severely affected ovaries were only 4-5 per ovariole (Plate-VI, Fig. E). However, the histological nature of these ovarioles revealed some recovery in its cellular structure especially in the germinal part. The descendenec of the oocytes from the germarium were quite normal and there was no retention of the oocytes. Generally, the oocytes had homogeneously granular ooplasm (Plate-VI, Fig. A) but in few older oocytes the ooplasm was vacuolized (Plate-VI, Fig. B). The interfollicular plugs and the follicular plug of the pedicel were also like those of the control ovarioles.

17.1.4. After Twenty Days

The anatomical structure of the ovaries of affected females after 20 days following the emergence from the 4^{th} instar nymphs treated with different concentrations (0.01, 0.008, 0.006, 0.004 and 0.002%) of dichlorvos was similar with those of the ovaries of ten days old females.

The histological picture of the ovarioles of these affected females revealed complete recovery from the damage as seen in younger females showing the cellular structure of these ovarioles quite similar with that of control females.

17.2. Effects on Ovaries of Adult Females Following Topical Application of Dichlorvos on 5th Instar Nymphs of *Dysdercus cingulatus* Fabr.

17.2.1. After One Day

The ovaries of the females which emerged following the application of different concentrations of dichlorvos on the 5th instar nymphs did not show any difference in the anatomical or histological structure as compared to those of the control.

17.2.2. After Five Days

After five days too, the ovaries of the affected females did not show any damage, or resorption of the oocytes. However, with respect to the application of the highest sublethal concentration (0.01%) on 5th instar nymphs the size of the ovaries was reduced as compared to control. Generally there were 7 to 8 oocytes in each ovariole as compared to 8 to 10 in the control, whereas, in some more severely affected ovaries, the number of oocytes in each ovariole was reduced to 4-5 (Plaate-VI, Fig. H). Further, the size of these oocytes was quite short.

There was only a slight damage in the prefollicular tissue of the germarium. In the trophocytes of the posterior region of the germarium, there was occasional clumping of the chromatin. In the vitellarium the oocytes were normal in shape but a few of them were smaller in size than those of the control of the corresponding age. The differentiation and the descent of the oocytes was unaffected. In some severely affected ovarioles, few oocytes in the vitellarium showed different stage of degeneration and resorption. In these oocytes, the ooplasm get condensed and vacuolized (Plate-VI, Fig. G).

17.2.3. After Ten Days

The anatomical structure of the ovaries of ten days old females which emerged from the survived treated nymphs showed some abnormalities as compared to those of the control females of corresponding age. The germarium and the vitellarium were clearly distinguishable and there was no downward movement of the germinal tissue into the vitellarium. However, the number of oocytes in the vitellarium was reduced to 4-5 and the size of the ovaries was smaller than control (Plate-VI, Fig. I). The lateral oviducts were proportionately longer.

The histological structure of the ovarioles of such females revealed cellular disorganization in the germarium. The anterior as well as most of the posterior portion of the germarium was quite intact like normal germarium having normal trophocytes. But at some places the chromatin of the nuclei of trophocytes was clumped. However, the descent of the oocytes from the germarium into the vitellarium was normal.

17.2.4. After Twenty Days

After twenty days following emergence of the affected females with respect to the application of sublethal concentrations of dichlorvos on the nymphs, the anatomical structure of the ovaries was normal except changes in size. The number of oocytes was same as compared to the normal females, however, their size was smaller. The germarium was intact and the differentiation was clear. Similarly, the cellular structure of these ovarioles showed some recovery from the damage and there was no clumping of chromatin.

18.1.Effects on Ovaries of Adult Females Following Topical Application of Furadan on 4th Instar Nymphs of *Dysdercus cingulatus* Fabr.

18.1.1. After One Day

The anatomical as well as the histological structure of the ovaries of one day old females which emerged from the 4th instar nymphs following the topical application of different concentrations of furadan, were almost like those of control females of the corresponding age. Both the germarium and the vitellarium were clearly differentiated from each other. However, the number of oocytes in the vitellarium was less as compared with that of normal females of similar age. Further, all the oocytes in the vitellarium were intact.

18.1.2. After Five Days

The anatomical structure of the ovaries of five-days old affected females emerged following the topical application of 0.001, 0.0008 and 0.0006% furadan showed a number of abnormalities. The growth of the ovarioles was affected and the over all size of the ovary was much reduced than that of the control females. Further, the discrimination between the germarium and the vitellarium became obscured in some ovarioles. Otherwise, the germarium was generally quite intact and their staining response with borax carmine was like that of normal ovarioles. In some affected females, there was inhibition in the development, descent and maturation of young oocytes in the vitellarium and generally not more than 4-5 oocytes of smaller size were present in each ovariole. Whereas in normal females of this age, vitellogenesis was complete and 8 to 10 oocytes matured in each ovariole, whereas, in some more severely affected ovaries only 2-3 matured oocytes were present in each ovariole (Plate-VII, Fig. E). The lateral oviducts of the affected females were proportionately longer than those of the control females.

The histological structure of the ovarioles of such females which emerged following the application of the higher concentrations (viz., 0.001, 0.0008 and 0.0006%) of furadan on the 4th instar nymphs revealed a number of anomalies and damages in its cellular structure. The cellular organization of the germarium in some ovarioles lost its originality, but in others, more than one third anterior portion of it was quite normal like those of control. Although, the shape and size of the germarium was unchanged, the trophocytes in the posterior region showed clumping of chromatin in their nuclei. In some cases disintegration of the trophic core began and small vacuoles appeared (Plate-VII, Fig. D). There was clumping of chromatin in the prefollicular cells leading to the decimation of the prefollicular tissue. Some oocytes in the germarium had a number of vacuoles indicating the commencement of degeneration. Although, the oocytes of the vitellarium appeared normal, these became smaller in size than the oocytes of the control females. In some severely affected ovaries, the oocytes in the vitellarium had medium sized vacuoles (Plate-VII, Fig. A). In most of the cases the nutritive cord became very thin and lost its connection with the trophic core. The follicular epithelium was comparatively thin, whereas, the interfollicular plugs as well as follicular plug near the pedicel were undamaged.

The anatomical structure of the ovaries of the affected females following the topical application of the lower selected concentrations (viz. 0.0004 and 0.0002%) on these nymphs were quite normal and were like those of unaffected females. Similarly, the histological picture of the ovarioles was also not affected adversely.

18.1.3. After Ten Days

As compared to the ovaries of unaffected females of similar age, the ovaries of ten day old affected females emerged from the affected nymphs following the application of 0.001, 0.0008 and 0.0006% furadan were much smaller in size. The degree of damage in all the ovarioles were not uniform and both the germarium and the vitellarium were distinguishable in the less affected ovarioles, whereas, in some cases the distinction between these two became obscured. The number of oocytes in each ovariole was also less. These oocytes were in various stages of maturation,

some of them were in advanced stage and also transformed into mature eggs with complete chorion around them. But these eggs were smaller in size and most of them were abnormal in appearance (plate-VII, fig.F). In some severely affected ovaries, only 1 or 2 oocytes were transformed into matured eggs with complete chorion arround them (Plate-VII, Fig. G).

The histological studies of these ovaries revealed varied effects of 0.001, 0.0008 and 0.0006% concentrations of furadan. The shape and size of the germarium appeared normal but its cellular structure was damaged. Most of the trophocytes of severely affected ovarioles showed clumping of chromatin. In the lower half region of the germarium, there were some irregular shaped oocytes which were under different stages of maturation. Further, the trophic core was also absent (Plate-X, Fig. C). The vitellarium was quite short and thick as compared with that of control, whereas, in the less affected ovarioles, the clumping of chromatin in trophocytes was rare and the trophic core was intact. The vitellarium was normal showing interfollicular plugs as well as follicular plug near the pedicel.

18.1.4. After Twenty Days

After twenty days of emergence, the ovaries of the affected females following the topical application of 0.001, 0.0008 and 0.0006% furadan on the nymphs showed much variation in its damage as compared to ten days old females. Some of the ovarioles were normal and intact in their anatomical structure, whereas, some other ovarioles were in various stages of recovery with only 4-6 eggs in each ovariole. Some of these eggs were normal while others were comparatively smaller and abnormal in shape. In some more severely affected ovaries, the ovarioles had only one fully matured eggs in the vitellarium (Plate-X, Fig. G). Although, chorion was secreted around the mature oocytes, most of these eggs were retained in the vitellarium. The ovarioles were comparatively smaller.

In histological organization, the ovaries of the females which were affected with higher concentrations showed some recovery in its cellular structure. The degree of clumping of chromatin in the trophocytes was reduced significantly as

compared to the prefollicular cells of the germarium. The density of the prefollicular cells was also reduced. In some ovarioles the follicular epithelium became comparatively thin and the nutritive cords were fragile as compared to the control, whereas, in most of the ovarioles, the follicular epithelium was quite normal and around the well developed oocytes the binucleate follicular cells were also present. The interfollicular plugs were almost like those of the control's ovaries.

The anatomical structure of the ovaries of affected females which emerged from the nymphs following topical application of 0.0004 and 0.0002% furadan were normal and similar with that of control females. Likewise, the histological structure of the ovarioles was also normal like that of the control.

18.2. Effects on Ovaries of Adult Females Following Topical Application of Furadan on 5th Instar Nymphs of *Dysdercus cingulatus* Fabr.

18.2.1. After One Day

The ovaries of one day old females which emerged from the 5th instar nymphs that were topically treated with 0.001, 0.0008 and 0.0006% concentrations of furadan showed no change in the anatomical as well as histological structure of the ovaries except in size which was comparatively shorter than the normal size. The germarium and the vitellarium were normal and prominently distinguishable.

18.2.2. After Five Days

The ovaries of the affected females following the topical application of the higher selected sublethal concentrations (viz. 0.001, 0.0008 and 0.0006%) on 5th instar nymphs developed irregular effects. Although, the ovaries of such females were much smaller than those of the control females of the corresponding age. The germarium and the vitellarium were recognizable in most of the ovarioles. The

control females aged 5 days completed the process of vitellogenesis and the chorion was laid around each oocyte. But in the affected females of this age some ovarioles had no sign of vitellogenesis, whereas, some had partial vitellogenesis in the oocytes of the vitellarium (Plate- VII, Fig. H). In a few ovarioles the follicular chambers were indistinct (Plate-VII, Fig. I). In certain severely affected ovaries, the distinction between the germarium and the vitellarium was obscured. The oocytes in the vitellarium were degenerated completely and resorbed finally (Plate-X, Fig. E). The lateral oviduct of the affected females were proportionately longer as compared to the control.

Histologically there was a number of anomalies in the ovarioles. Although, there was irregular damage in the germarium, the shape and size of the ovarioles was intact. In less affected ovarioles, almost all the trophocytes were normal and intact but in case of severely affected ovarioles, most of the trophocytes in the posterior region showed clumping of chromatin. The trophic core was mostly intact, whereas, in a few cases there was beginning of degeneration. The number of prefollicular cells was also reduced but in some cases these cells were absent. Although, the vitellogenesis was largely normal, some of the oocytes had slow vitellogeneis and the ooplasm of these oocytes was homogeneously granular with traces of yolk deposits. However, there was frequent appearance of vacuoles (Plate-VII, Fig. B). Further, these oocytes were smaller in size and the nutritive cord was thinner than the control. The number of oocytes in the vitellarium was 5 to 7 as compared to 8-10 in the normal females. The follicular epithelium, interfollicular plugs and the follicular plug near the pedicel were undamaged.

However, the topical application of the lower concentrations of furadan (0.0004 and 0.0002%) on the nymphs did not cause damage to the ovaries of the affected females and the size of the ovaries as well as number of oocytes in each ovariole were almost similar to the control. The histological organization of such ovarioles was quite normal and vitellogenesis was similar to that of the control.

18.2.3. After Ten Days

The ovaries of ten days old affected females which emerged following the topical application of 0.001, 0.0008 and 0.0006% furadan on nymphs also developed irregular anatomical damages. The size of the ovaries was mostly smaller than those of the control but the germarium as well as vitellarium were clearly differentiated from each other. The number of oocytes in each ovariole was reduced. The less affected ovaries had only 4 to 6 oocytes per ovariole which were in the advanced stage of the development, whereas, the more severely affected ovaries had only 1 or 2 oocytes in each ovariole. In few cases, there was retention of 1 or 2 matured eggs in the vitellarium (Plate-VII, Fig. J). The ovaries of the affected females which emerged from the nymphs following the topical application of 0.001, 0.0008 and 0.0006% furadan showed scattered chromatin clumping in some trophocytes as well as in some prefollicular cells. In a few ovarioles, there was retention of the oocytes in the germarium and the number of prefollicular cells was also reduced. The oocytes in the vitellarium were smaller in size. In some ovarioles, the oocytes of the posterior region had a number of yolk globules but these were vacuolated and their vitelline membrane as well as chorion were still lacking as compared to others which were normal during maturation process (Plate-VII, Fig. C). Further, in some ovarioles the follicular epithelium as well as the wall of the pedicel became thinner than that of the unaffected females.

However, the lower concentrations (0.0004 and 0.0002%) did not show any anatomical or histological damage in the ovaries of the emerged females. The ovarioles were quite intact and the maturation of the oocytes were normal.

18.2.4. After Twenty Days

The anatomical as well as histological structure of the ovaries of twenty days old females which had emerged following the topical application of different concentrations of furadan on the nymphs did not show any significant advancement in their damage and the ovarioles of the females almost remained like those of the

ten days old affected females. Further, in a few ovarioles, some recovery in the cellular damage was recorded.

19.1. Effects on Ovaries of Adult Females Following Topical Application of Carbaryl on 4th Instar Nymphs of *Dysdercus cingulatus* Fabr.

19.1.1. After One Day

The ovaries of affected females were like that of control with respect to all concentrations of carbaryl.

19.1.2. After Five Days

The growth in the size of the ovarioles of the affected females which emerged following the topical application of 0.0025 and 0.0020% carbaryl/nymph was less pronounced as compared with that of the control females. Generally, there were 6-8 smaller oocytes in each vitellarium of affected females as compared to 8-10 oocytes in control females, whereas, in some severely affected ovaries (0.0025%), there were only 2-3 oocytes in each vitellarium (Plate-VIII, Fig. D). These oocytes were not arranged in normal successive linear fashion (Plate-VIII, Fig.E). However, following the topical application of the weaker concentrations of carbaryl (0.0015, 0.0010, 0.0005%) on the 4th instar nymphs, the ovarioles of the affected females were anatomically like those of control females. The histological observations of these ovarioles revealed that the shape and size of the germarium was normal, its internal cellular structure was changed in the posterior part where trophocytes showed clumping of the chromatin in their nuclei (Plate-VIII, Fig. C). In some cases, the trophic core showed beginning of disintegration and appearance of small vacuoles in the germarium. Further, some of the differentiated oocytes remained in the prefollicular region and could not descend properly in the previtellarium as compared to the control. At some places there was clumping of chromatin in the

prefollicular cells leading to the decimation of the tissue. Some of the oocytes in the previtellarium were grouped in twos or threes in one egg chamber, and due to the pairing of prefollicular cells, compound egg chambers were formed in the previtellarium. There were no follicular cells between the oocytes of a compound egg chamber but only a common follicular epithelium surrounded these oocytes. In the normal females the prefollicular cell reserves remain sufficient to envelop each newly descended oocyte in the vitellarium even in very old females. Between the older oocytes of the vitellarium, the interfollicular cells did not form the interfollicular plug like that of the normal ovarioles. Instead, there was a single layer of cells forming a thin septum between the adjacent chambers (Plate-VIII, Fig.B). In the affected ovarioles the ooplasm of the younger oocytes was intact and homogeneously granular but the ooplasm of some of the older oocytes was vacuolized.

19.1.3. After Ten Days

After ten days following emergence, the ovaries of the affected females treated with 0.0025, and 0.002% concentrations were much smaller than that of the normal females of corresponding age. Anatomically, germarium was quite intact and took dark stain of borax carmine like that of normal ovarioles and was clearly differentiated from the vitellarium. The oocytes were clearly visible in the vitellarium but some were smaller in size as compared to that of normal ovaries. In few ovaries, the development and maturation of the oocytes in the vitellarium were not uniform. In some ovarioles 1 or 2 oocytes get fully matured, whereas, the remaining oocytes were small and showed no sign of development (Plate-VIII, Fig. F). The lateral oviducts of the affected females were much longer than those of the unaffected females. However, the topical application of lower sublethal concentrations (0.0015, 0.0010 and 0.0005%) of carbaryl did not cause any damage and all the ovarioles appeared normal.

However, in histological observations some changes were recorded, though it was not uniform in all ovarioles of a single ovary of the affected females which emerged from the 4^{th} instar nymphs following the topical application of 0.0025 and

0.0020% carbaryl. The trophocytes present in the anterior half of the germarium were quite normal. But in the lower half of the germarium some trophocytes showed beginning of disintegration and clumping of chromatin in their nuclei. The trophic core also showed small vacuoles. The clumping of chromatin in a few prefollicular cells of the lower portion of germarium was also observed. Further, the oocytes of the vitellarium were smaller in size and lesser in number as compared with that of the control. The follicular epithelium was comparatively thin and the interfollicular plugs became like thin septa.

19.1.4. After Twenty Days

The ovaries of the twenty days old affected females did not show any advancement in the damage. The germarium and vitellarium were quite distinguishable. Some of the ovaries were normal in one half while the other half was damaged slightly. There was also indication of oviposition, although in all cases some of the matured eggs were retained in the ovarioles. However, the topical application of the lower concentrations (viz. 0.0015, 0.0010 and 0.0005%) on the 4th instar nymphs did not change the anatomical structure of the ovarioles and the ovaries were similar like that of the control.

The histological picture of the ovaries of the affected females emerged following the topical application of 0.0025 and 0.0020% carbaryl did not show any further deterioration of the ovarioles. Instead, in some cases recovery in the cellular structure of the germarium was apparent. The trophocytes, trophic core and the prefollicular cells were normal, however, a few trophocytes as well as prefollicular cells showed little clumping of chromatin. The oocytes of the vitellarium were smaller in size in comparison to the control. However, the follicular epithelium and the interfollicular plugs as well as follicular plug were normal. The topical application of the lower concentrations of the carbaryl did not affect the cellular structure of the ovaries.

19.2. Effects on Ovaries of Adult Females Following Topical Application of Carbaryl on 5th Instar Nymphs of *Dysdercus cingulatus* Fabr.

19.2.1. After One Day

The ovaries of affected females after one day were anatomically as well as histologically same as those of control females.

19.2.2. After Five Days

The ovaries of five days old affected females following the topical application of said concentrations did not show any marked damage in the anatomical structure. The size of the ovarioles was adversely affected with reference to 0.0025 and 0.0020% carbaryl. The size and shape of the germarium was intact and it was clearly differentiated from the vitellarium. The number of oocytes in some ovarioles were 3-4 and these were smaller in size as compared to the control(Plate-VIII, Fig. G). In some cases, the matured oocytes in the vitellarium were not arranged linearly (Plate-VIII, Fig. I). The ovaries of the affected females which emerged from the topically treated nymphs with 0.0015, 0.0010 and 0.0005% carbaryl were structurally the same as those of normal females (control).

In the ovarioles of the affected females, which emerged from treated nymphs following the application of 0.0025 and 0.0020% carbaryl, the germarium were mostly normal. However, in some ovarioles few prefollicular cells as well as the trophocytes which surround the trophic core had clumping of chromatin. The trophic core was comparatively smaller and quite fragile. The density of the prefollicular cells was also reduced. The number of oocytes in the vitellarium was also less in comparison with that of normal females. In some ovarioles, the young oocytes were retained in the germarium and there was no indication of vitellogenesis. Instead, most of them had vacuoles. The interfollicular plugs of these ovarioles were thinner than that of normal ovarioles. The follicular epithelium was thin and the nuclei of

some of its cells showed clumping of chromatin. However, the ovaries of the females affected by lower concentrations of carbaryl (0.0015, 0.0010 and 0.0005%) did not reveal any cytological damage in the ovarioles.

19.2.3. After Ten Days

The ovaries of the females affected by 0.0025 and 0.0020% carbaryl during ten days following emergence developed some changes in their anatomical structure. The size of the ovaries was smaller than that of control females of the corresponding age. The anatomical distinction between the germarium and the vitellarium was clear except in a few ovarioles. In some cases, there were only 2-5 oocytes in each ovariole which were in various stages of maturation. These oocytes were not arranged linearly. Some of the oocytes also transformed into mature eggs with complete chorion around them. But these matured eggs were comparatively smaller in size and many of them were abnormally shaped (Plate-VIII, Fig. H). During this stretch of time following emergence, untreated females had two ovipositions, whereas, some of the affected females had only one. The topical application of lower concentrations on the nymphs (viz. 0.0015, 0.0010 and 0.0005%) did not show any type of anatomical disorder in the ovaries of the affected females.

In histological preparations, the cellular picture of these ovarioles showed some anomalous changes which were almost similar to those of five days old affected females emerged from the nymphs topically treated with 0.0025 and 0.0020% carbaryl. The trophic core was intact but fragile except in a few germaria. The nature of damage in all the ovarioles was not uniform. In some ovarioles the vitellarium was quite normal showing interfollicular plugs and the follicular plug near the pedicel. However, in some other oocytes in the vitellarium, interfollicular plugs as well as the follicular plug near the base of the ovariole showed degeneration. The follicular epithelium of these ovarioles and the wall of the pedicel became comparatively thinner than that of the control. Vitellogenesis also occurred in the oocytes of the vitellarium but some oocytes developed vacuoles. In some oocytes

the deposition of yolk spheres were less (Plate-VIII, Fig. A). The secretion of the chorion was also evident around the matured oocytes. Whereas the topical application of all the selected lower concentrations of carbaryl on the nymphs did not develop any anomalous change in the cellular structure of the ovaries of the affected females.

19.2.4. After Twenty Days

After twenty days following emergence, there was no significant advancement of changes in the anatomical as well as histological structures of the ovaries and they remained almost like those of ten days old affected females or even showed some recovery in case of females affected by 0.0025 and 0.0020% carbaryl.

20.1. Effects on Ovaries of Adult Females Following Topical Application of Aminocarb on 4th Instar Nymphs of *Dysdercus cingulatus* Fabr.

20.1.1. After One Day

The ovaries of one day old females, which emerged from the 4th instar treated nymphs following the topical application of 0.004, 0.002 0.001, 0.0008 and 0.0006% aminocarb, were mostly of the same shape and size as in normal females. The germarium was intact, normal in size and clearly differentiated from vitellarium as in control case. But some oocytes in the vitellarium showed disintegration. The size of the lateral oviduct was slightly enlarged.

The cellular structure of the ovaries of the females which emerged from the treated nymphs, had no appreciable change as compared to normal females. In most of the ovarioles, the shape and cellular organization of the germarium and vitellarium was unchanged. The number of oocytes was normal, however, their size was smaller than those of the unaffected females.

20.1.2. After Five Days

The ovaries of the five days old females, following the emergence from the 4th nymphs treated with higher concentrations (0.004, 0.002 and 0.001%), were shorter in length and width as compared to control females. In the normal ovaries, there were 8 to 10 oocytes in each viterllarium, whereas, the affected females generally had only 5 to 6 oocytes/ovariole when the treatment was made with 0.004% and 0.002% aminocarb (Plate-IX, Fig. F). The size of the lateral oviducts was enlarged proportionately as compared to the control. In certain severely affected ovaries, the number of matured oocytes per ovariole were 2-3 (Plate-IX, Fig. E).

When examined histologically, the ovaries of five days old affected females revealed some anomalous changes. The nature of damage in the cellular picture of the germarium was like that of one day old affected females except in the lower half portion where some maturing oocytes merged together to form a compound oocyte with irregular yolk deposition and vacuolization. In the vitellarium, the size of the oocytes was smaller. The deposition of yolk was also low and the ooplasm was not homogeneously granular (Plate-IX, Fig. A). The interfollicular plugs as well as follicular plug near the pedicel was intact.

20.1.3. After Ten Days

After ten days following the emergence of the females, the size of the ovaries was normal as compared to the control. The distinction between the germarium and the vitellarium was clear. The shape and size of the germarium was also normal, but the egg chambers of the vitellarium were smaller as well as fewer than those of the unaffected females of the corresponding age. In some severely affected ovaries, the growth and maturation of the oocytes in the vitellarium were not uniform and these oocytes were not arranged in normal linear fashion (Plate-IX, Fig. G).

The cellular structure of the ovaries of the emerged females from the treated nymphs revealed some recovery especially in the lower half portion of the

germarium. Most of the oocytes were normal while a few had vacuoles (Plate-IX, Fig. B). The follicular epithelium around the well developed oocytes was quit normal. The interfollicular plugs as well as the follicular plug were similar to the normal females.

20.1.4. After Twenty Days

The nature of damage in the ovaries of twenty days old affected females did not show much difference and the anatomical structure remained the same as that of ten days old affected females. But in some severely affected ovaries, there were only 2-3 oocytes in the vitellarium which were mostly elongated. The vitellogenesis in these oocytes was completed and the chorion was also secreted arround them (Plate-IX, Fig.I).

Similarly, the histological changes in these ovaries were also similar to that of ten days old fernales.

20.2. Effects on Ovaries of Adult Females Following Topical Application of Aminocarb on 5th Instar Nymphs of *Dysdercus cingulatus* Fabr.

20.2.1. After One Day

The ovaries of one day old affected females were like those of the control females in their anatomical features. The germarium and the vitellarium were clearly differentiated from each other.

The cellular nature of the germarium (trophocytes, trophic core) and the vitellarium (oocytes and ooplasm) was normal.

20.2.2. After Five Days

The anatomical structure of the ovaries of the affected females emerged following the application of 0.004, 0.002 and 0.001% aminocarb revealed a few anomalies as compared to that of the control females of the corresponding age. The size of the ovaries of the affected females was shorter than those of the normal females. The size of the lateral oviducts was proportionately enlarged. In certain severely affected ovaries (0.004%), the oocytes in the vitellarium showed different stages of degeneration and resorption (Plate-IX, Fig. K). When these ovaries were examined histologically, the anterior most part of the germarium was normal, whereas, in the posterior region, clumping of chromatin in some trophocytes as well as in a few prefollicular cells was recorded (Plate-IX, Fig. D). The commencement of vitellogenesis in some oocytes was delayed, whereas, in normal females of the corresponding age, active vitellogenesis occurred at this stage. A number of small sized vacuoles appeared in the ooplasm of those oocytes where the vitellogenesis was delayed. The shape and size of these oocytes were irregular and the deposition of yolk in such oocytes was low (Plate-IX, Fig. C).

20.2.3. After Ten Days

After ten days following the emergence, the nature of damage in the ovaries of the affected females emerged from the 5th instar treated nymphs with 0.004, 0.002 and 0.001% aminocarb were like those of five days old affected females. The size of these ovaries was smaller than those of the control. However, the shape and size of the germarium was intact and anatomically the differentiation between the germarium and the vitellarium was clear, however, the ovarioles were unequal in length.

Histologically, the germarium was unchanged showing trophocytes, trophic core, prefollicular cells and young oocytes intact. However, the vitellarium was shorter than that of the normal females and maturation of some oocytes was in disorderly manner. In certain severely affected ovaries, the oocytes in the vitellarium had small vacuoles and their shape and size were irregular. The deposition of yolk

in these oocytes was also very low (Plate-IX, Fig. H). In some oocytes, the follicular epithelium was devoid of nutritive cords. The interfollicular plugs and follicular plug near the pedicel were normal.

20.2.4. After Twenty Days

The ovaries of the twenty days old females, following the emergence from the 5th nymphs treated with 0.004, 0.002 and 0.001% aminocarb, generally did not showed any advancement in the damage and were almost like those of ten days old. The shape and size of the germarium was normal, whereas, the size of the vitellarium was reduced. In some more severely affected ovaries, varied effects were observed and few ovarioles were completely empty except a little debris of the disintegrated cells were present near its base, whereas, some other ovarioles have small immature oocytes while few were as large as that of normal and also had matured eggs. But the arrangement of these eggs was anomalous (Plate-IX, Fig. J). The lateral oviducts were wider than normal. The oocytes had matured but their arrangement was anomalous. Some of the matured eggs were always retained in the ovaries.

The histological picture of the ovaries of these affected females revealed that the germarium cells were intact. Often the size of the vitellarium was short but the cellular structure showed some recovery. The interfollicular plugs and the follicular plug near the pedicel were normal.

21. Anatomical and Histological Observations on The Gonads of *Diacrisia obliqua* Walk. (Lepidoptera: Arctiidae)

21.1. Male reproductive organs

The male reproductive system of *D.obliqua* consists of single globular testis (Tes.) formed by the complete fusion of the two testes, a paired vasa differentia (Vd), a paired seminal vesicle (Vsm) with a duct (dvsm), a pair of accessory glands (AcGl), a common ejaculatory duct (Dej) and an aedeagus (Aed.). From the testes each vasa differentia opens into the corresponding seminal vesicle. The seminal vesicle gives out a narrow seminal duct which opens into a reservoir (Res AcGl) formed by the basal dilated part of the long, narrow and convoluted accessory gland. The reservoirs of both the sides converge posteriorly and form a common duct of the accessory glands (CdAcGl). This large common duct is highly convoluted and opens into the ejaculatory duct (Dej.) which finally enters into the aedeagus (Aed) and opens at the apex of the invaginated endophallus (Plate-XII, Fig.B).

Testes (Tes). The testis is pink in colour, spherical in shape and placed dorsally to the alimentary canal in the fifth abdominal segment. This single testis is formed by the complete fusion of the two testes which are enclosed in a single distinct peritoneal sheath. The latter is wrapped externally by fine branches of trachea.

The testis consists of eight testicular follicles (fol) which are separated from each other by incomplete septa (Sep.) Inner to the external peritoneum there are two distinct epithelial layers. The outer epithelium is thin and consists of a single row of cells which are closely packed with oval nuclei (nuc) which are scattered without definite plane. The cytoplasm is granular. The inner epithelium is comparatively thick and contains pigment granules which give pink colour to the testes. The nuclei of this epithelium are oval and more numerous. Further, the inner epithelium is continued for short distance into the testicular lumen in the form of seven filamentous septa (sep.) which divide the testes into eight incomplete testicular follicles (fol.). Each septa is thin apically, and gradually becomes thick at the base.

The lumen of the testes contains germ cells showing various stages of development. The primary germ cells or spermatogonia (Spg.) show spermatogenesis and daughter spermatogonia are encysted to form the sperm cysts (Cst), later developing into spermatids (Spd.) which finally transform into bundles of mature spermatozoa known as spermatodians (Spz.). The free spermatozoa are not present in the lumen of the testes.

Vas deferens (Vd). The two broad based vas-deferentia originate from the posterioventral side of the testes and then run as narrow tube to open into the seminal vesicle which continues as narrow seminal duct to join the reservoir of the accessory glands. The peritoneal layer of the testes continues to form the outermost covering of the vas deferens and the seminal vesicle.

Accessory glands(AcGl). There are a pair of long, and narrow accessory glands which are bound closer to each other by the trachae. Each gland is uniform in width but blind apically and basely opens into its reservoir, which is short and dilated tube which opens posteriorly into the common duct of the accessory glands. This common duct is long, tubular and highly convoluted and directly opens into the ejaculatory duct.

Ejaculatory duct (Dej). The ejaculatory duct is short, convoluted and dilate to form a broad bulb like structure known as bulbous ejaculatorious (Bej.). It is broader at its posterior end and measures about one third of the length of the common duct of the accessory glands. The whole ejaculatory duct is covered by a thin peritoneal membrane. It becomes narrow before entering aedeagus and opens at the apex of the endophallus through the gonopore.

21.2. Female reproductive organs

The female reproductive organs of *D. obliqua* wlk. consists of a pair of ovaries (Ov), two lateral oviducts (Odl), a short common oviduct (Odc) and a vagina (Veg.) which opens outside through the oviporus. Each ovary consists of four ovarioles

(Ovl) opening into a short lateral oviduct posteriorly. The two lateral oviducts unite to form a short common oviduct. There is a thick walled sac known as bursa copulatrix (bcpx) situated below the ovarioles and anterior to the common oviduct. From the basal region of the bursa copulatrix, a short duct i.e. bursal duct (bd) originates and opens into the dilated distal part of the oviduct i.e. vagina. There is a pair of accessory glands (AcGl) which unite posteriorly to open dorsally into the common oviduct. There is single spermatheca which is long and slightly coiled and its middle part known as spermathecal resirvoir (Spr) is wider in diameter. It opens into the vagina, anterior to the opening of bursa copulatrix (Plate-XII, Fig. A).

Ovary (Ov). Each ovary is large, conspicuous and lies dorso-lateral to the alimentary canal. It consists of four polytrophic ovarioles. When the ovaries mature they occupy the whole portion of the visceral sinus. Each ovariole is very large and coiled and all the ovarioles are bound with trachae and fat body. Posteriorly, the four ovarioles of each ovary unite to open into the lateral oviduct.

Ovariole (Ovl). Each ovariole consists of two regions, the apical germarium (Grm) and long vitellarium (Vtl) which is the major portion. The germarium is externally enclosed in a thin, smooth and non-nucleated peritoneal layer (ps) and it is packed with primordial germ cells (pgc) which are subsequently differentiated into the oocytes (Ooc), nurse cells (Nrc) and the follicular cells (fc). The germarium is followed by the beaded vitellarium. These beads are the follicles (egg chambers) which relatively enlarge posteriorly as maturation progresses. Each follicle (fo) is a compound structure containing a group of nurse cells anteriorly and a developing oocyte posteriorly. The follicular epithelium (fEpth) around the oocyte is made up of columnar cells, whereas, portion which surrounds the nurse cells consists of cuboidal cells. The follicle cells are borne on a distinct basement membrane (BMB).

The nutritive cells (NrC) are large and irregular with granulated cytoplasm and big nuclei (nuN) which is poorly granulated. Disintegrated nurse cells are seen as the growth and maturation of oocytes proceeds. Each oocyte is spherical in shape with rounded nucleus (N). A structureless chorion (ch) is present around the fully developed oocyte.

Oviducts (Od). The four ovarioles of each ovary basally unite to form a single duct known as the lateral oviduct which opens into a short common oviduct. The histological details of the lateral duct and the common duct are almost similar to each other. The wall of the lateral and common oviduct is made up of a muscularis layer consisting of an outer thick layer of longitudinal muscles (lmcl) and an inner layer of circular muscle fibres (Cmcl). Internally the muscularis layer is lined by an epithelium (Epth) which rests on a basement membrane. The epithelium is made up of small cuboidal cells with light boundaries but with prominent nuclei, and the cytoplasm as well as nuclei are densely granulated (gn).

Vagina (Vej). The short common oviduct opens into a dilated part called vagina (Veg) which is almost uniform in diameter and communicates to exterior through the oviporus. Anatomically, anterior as well as posterior limits of vagina are marked by the opening of the spermatheca as well as accessory glands, respectively.

Spermatheca (Spt). The spermatheca is tubular in shape and opens into the vagina through a short spermathecal duct, basally it is dilated to form a distinct reservoir (Spr) which is coiled among the female reproductive organs. Its lumen is narrow and surrounded by wavery chitinous lining (In). The lumen of the spirally coiled spermathecal duct is much reduced due to the deep villi borne by the epithelium.

Bursa Copulatrix (bcpx). There is a large thick walled sac like structure situated below the ovarioles and anterior to the common oviduct. There is a short bursal duct (bd) arising from the bursal orifice (bo) and extended into the visceral sinus under the digestive tract. This bursal duct or the seminal duct connects the bursa copulatrix with the vagina. The bursal duct is curved and dorso-ventrally flattened.

Seminal duct (Sd). The seminal duct (Sd) is a thin and narrow tube which connects the bursal duct with the vagina. The proximal half of the seminal duct is broader as compared to its distal half. From the middle part of this duct a small diverticulum is given out (bsem).

Accessory glands (AcGl). There is a pair of accessory glands which are large, tubular and convoluted structure lying in the posterior region of the visceral sinus. Each gland, before opening, dilates to form a sac like reservoir (ResAcGl). The latter, is placed dorsal to the rectum. The reservoir tapers behind and unites with its counter part of the other side. The fused portion is drawn out into a short, narrow duct of the accessory gland (d AcGl) which opens into the lateral wall of the vagina. The fluid discharge of the gland is transparent and is used for gluing the eggs on the substratum. This is evident by the fact that the fully filled reservoirs always get shrinked after oviposition.

Attractant gland (Sg). There is a pair of convoluted, narrow and tubular gland (Sg) lying in the visceral sinus of the female. These two glands unite posteriorly to form a short common duct. The secretion of these glands serves to attract the counter sex for mating.

22.1. Effects on Ovaries of Adult Females Following Topical Application of Acephate on 5th Instar Larvae of *D. obliqua* Wlk.

The males and the females that emerged from the topically treated 5th instar larvae (one day old) by 0.02, 0.04, 0.06, 0.08 and 0.10% acephate were kept in ten pairs.

The ovaries of the two days old females which emerged from the survived treated larvae following the topical application of 0.10 and 0.08% concentrations showed some anatomical deformities. The size of the ovaries of the affected females was smaller as compared to unaffected (control-I) females (Plate-XIV, Fig. E-F). The germarium and the vitellarium were clearly distinguishable. Although, the length of each ovariole was normal, there was loose arrangement of chorionated eggs at the base of some ovarioles. In addition, there was formation of an ovariole loop (Plate-XII, Fig. D) and the common oviduct became slightly broader as compared to that of control females. The bursa copulatrix became comparatively

small and less sclerotized. Although, the shape of the accessory glands was unchanged, its size was reduced proportionately with respect to the size of the ovary as compared to that of the control. However, the females which emerged from the larvae treated with 0.06, 0.04 and 0.02% acephate did not show any remarkable damage in the anatomical structure of their ovaries. The shape and size of the ovaries of the affected females was almost similar to that of the control-I.

The ovarioles of the affected females following the topical application of 0.10, 0.08 and 0.06% acephate on the larvae showed cellular damage. The nature of the changes was almost identical with respect to each treatment but the degree of damages varied with concentrations. The linear arrangement of both immature and mature eggs in certain ovarioles was not uniform (Plate-XIV, Fig. B)and the density of ooplasm was very thin in the oocytes. The accumulation of yolk protein spheres at the egg cortex was not normal in the eggs of the same region of the ovarioles as evident by differential staining property(Plate-XIV, Fig. D). In some ovarioles the ooplasm of the chorionated eggs developed differential growth pattern including the accumulation of the yolk protein spheres as compared to normal pattern of the controls. The staining property of these oocytes showed their young condition though their accompanying trophocytes were almost exhausted. The follicle cells of immature oocytes in few cases, had loose arrangement leaving some space between them. The trophocytes in some ovarioles became short and loosely arranged. The ovarioles of the affected females by lower concentrations of acephate had either insignificant effect or no damage at all. The histological picture of the ovaries of these females was almost identical with that of the unaffected (control-I) females.

22.2. Effects on Ovaries of Adult Females Following Topical Application of Acephate on 6th Instar Larvae of *D. obliqua* Wlk.

The anatomical study of the ovaries of two days old females which emerged following the topical application of 0.10 and 0.08% acephate, revealed reduction in their size as compared to that of the control (Plaate-XIV, Fig. G-I). The development of oocytes was slow in the vitellarial portion and a loose arrangement of the chorionated eggs was also evident on the junction of some ovarioles with the lateral oviducts. In some ovarioles more than one oocytes were present in a single egg chamber resulting in the formation of compound egg chamber. The shape and size of the lateral and the common oviducts as well as spermathecae were unchanged. But the bursa copulatrix of the affected females was enlarged as compared to that of the control. The size of the accessory gland was normal, whereas, there were one or two wrinkles, which appeared due to the lack of contents. There was no remarkable damage in anatomical structure with respect to the application of the lower concentrations (viz., 0.06, 0.04 and 0.02%). The shape and size of the ovaries of the affected females was like that of the (control) unaffected females.

The histological picture of the ovarioles of the affected females of the larvae topically applied with 0.1 and 0.08% acephate had nature of changes almost the same for both the stocks but the degree of damage was less as compared to the females which emerged from the 5th instar treated larvae. The damages were dose based. The germinal part of the ovariole was intact having normal primordial germ cells. Below the germarium, there was a long immature vitellarial portion which contained more immature oocytes as compared to control. The development of these oocytes was rather slow and contained less ooplasm as compared to the control. Below this portion, the ovarioles had the chorionated eggs. The accumulation of yolk protein in the eggs was not normal as indicated by the differential staining property of such eggs of the same region (Plate-XIV, Fig. A). In some cases the egg chamber was found having small nurse cells with less granulated cytoplasm. However, in most of the cases the nurse cells were large, irregular in shape having slightly granulated cytoplasm. Furthermore, the follicular

epithelium was mostly normal, except in a few cases where its columnar cells were loosely arranged. The topical application of the lower concentrations (0.06, 0.04 and 0.02%) of acephate on the larvae did not show any remarkable changes in the ovaries of the affected females.

23.1. Effects on Ovaries of Adult Females Following Topical Application of Ethion on 5th Instar Larvae of *D. obliqua* Wlk.

The males and females which emerged from the topically treated 5th instar larvae (one day old) by 0.6, 0.4, 0.2, 0.1 and 0.08% ethion were kept in ten pairs.

Anatomically the ovaries of two days old affected females which emerged from the treated larvae by the topical application of 0.6, 0.4 and 0.2% ethion were smaller in size as compared to the control (Plate XV, Fig. E-G). Although, the germarium and the vitellarium were clearly distinguishable, the terminal filaments of the ovarioles were much reduced. In some cases the ovarioles terminated freely, whereas, in others the free ends were filamentous and much longer. The size of the vitellarium was reduced remarkably as compared to that of the control. Some ovarioles had loop formation and at some places several oocytes were grouped in a single egg chamber (Plate-XV, Fig. C). The bursa copulatrix which is fairly large sac like structure in the normal females, became slender and slightly short and delicate as compared to control-I. The accessory glands were comparatively thin and short. However, such adverse effects were not formed in the ovaries of the females which emerged from the larvae treated with 0.10 and 0.08% ethion.

The topical application of 0.6, 0.4 and 0.2% ethion/5th instar larva of *D. obliqua* developed some histological changes in the ovarioles of the affected females. In most of the ovarioles the immature part of the vitellarium contained young normal oocytes. However, in some cases these immature oocytes had only small trophocytes with irregular cytoplasm. The development of these oocytes was very slow as compared to the other oocytes of the same ovary where the

development and maturation were normal and linear. In the normal development of the oocytes the trophocytes moved towards the upper region but in a few cases, the movement of these cells was not clear. In yet other cases, the development of some oocytes was slow, showing a very young condition even though their trophocytes were totally exhausted. In most of the cases, the formation of chorion membrane started normally but some of the chorionating eggs were smaller in size and contained less yolk as compared to the control (Plate-XV, Fig. B). Further, the number of the chorionated eggs fell short of the normal count as compared to the control. Although, the cellular structure of the lateral oviducts was unchanged, in few cases the epithelium contained more flattened cuboidal cells and had less thick longitudinal (lmcl) and circular muscle (cimcl) fibres layer as compared to the unaffected females. In some spermatheca the epithelial cells were smaller in size and contained less granulated cytoplasm as compared to the control. The lumen of these glands was reduced and had less prominent wavy chitinous lining. The histological nature of the ovaries of the affected females following the application of 0.1% and 0.08% ethion was almost similar to that of control females.

23.2. Effects on Ovaries of Adult Females Following Topical Application of Ethion on 6th Instar Larvae of *D. obliqua* Wlk.

The males and females which emerged from the topically treated 6th instar larvae (one day old) by 0.6, 0.4, 0.2, 0.1 and 0.08% ethion were kept in ten pairs.

The anatomical structure of the ovaries of two days old females which emerged from the larvae following the topical application of 0.6, 0.4 and 0.2% ethion showed remarkably reduced size of the ovaries (Plate-XV, Fig. H-I). The length of the immature part of the vitellarium was longer and less beaded, whereas, the size of the mature part of the vitellarium was proportionately shorter as compared to that of the control. Further, the number of chorionated eggs at the base of the ovarioles was also reduced as compared to the chorionating eggs. The shape and size of the common oviduct became slightly broader and comparatively shorter as compared to

that of the unaffected (control) females. The bursa copulatrix became slender and less sclerotized as compared to that of the control-I. The topical application of 0.1 and 0.8% ethion did not show adverse anatomical conditions in the ovaries of the females which emerged from the treated larvae.

The histological structure of the ovaries of the females emerged from the larvae topically treated with 0.6, 0.4 and 0.2% ethion showed some remarkable anomalies in their ovarioles. The cellular structure of the germinal portion was intact which contained large number of primordial germ cells. In the posterior region, each primary oogonia was enclosed in a thin epithelial layer alongwith few trophocytes. The apical portion of the vitellarium contained immature oocytes which were not arranged linearly. In some ovarioles the follicular epithelium was thin and contained loose cuboidal cells. These oocytes had thin ooplasm and had developed few small vacuoles at the centre and were smaller in size as compared to the other oocytes of the same ovary(Plate-XV, Fig. A). The number of chorionating eggs were less as compared to that of the control females. The posterior part of some ovarioles had egg chambers still containing underdeveloped oocytes, even though their trophocytes had disintegrated completely (Plate-XV, Fig. D). Furthermore, the follicular cells of these oocytes shrunk and later degenerated. The thickness of the longitudinal and circular muscle fibres of the lateral oviducts was reduced slightly. In a few cases of spermatheca, the lumen was lined with a thin layer of light brown intima as compared to unaffected (control). When the topical treatment was made with the lower concentrations (i.e. 0.1 and 0.08%) of ethion on the larvae the histological picture of the ovarioles of emerged females remained unaffected.

24.1. Effects on Ovaries of Adult Females Following Topical Application of Dichlorvos on 5th Instar Larvae of *D. obliqua* Wlk.

The males and females which emerged from the topically treated 5th instar larvae (one day old) by 0.4, 0.2, 0.1, 0.08 and 0.06% dichlorvos were kept in ten pairs.

The females which emerged from the survived treated larvae by the topical application of 0.4, 0.2 and 0.1% dichlorvos had small ovaries as compared to that of acephate affected females as well as that of the females from untreated larvae (Plate-XVI, Fig. E,F,I). Furthermore, the size of the germarium was also reduced slightly, although the distinction between the germarium and vitellarium was clear. The length of the vitellarium was slightly shorter as compared to control. In some cases, few ovarioles had a formation of loop, while in others a narrow empty space developed (Plate-XVI, Fig. C). The terminal bundle of each ovary was reduced considerably as compared to that of the control. The number of eggs in a ovariole were also less than the unaffected (control) specimen, occasionally there were more than one oocytes in a single egg chamber (Plate-XVI, Fig. C). In some cases, the accumulation of chorionated eggs was also observed at the junction of the ovarioles with the lateral oviduct (Plate-XX, Fig. C). The shape of the lateral oviducts as well as the common oviduct was normal, however, the size of the lateral oviduct was reduced proportionately as compared to that of control females. Similarly, the size of the bursa copulatrix was slightly small and less sclerotized. The ovaries of the females from the larvae topically treated with 0.08 and 0.06% dichlorvos showed no anatomical changes.

The ovarioles developed some cellular anomalies in case of the females of the stock of larvae treated by 0.4, 0.2 and 0.1% dichlorvos. Although, the cellular organization of the germarium was unchanged and the primordial germ cells were normal, their number was less as compared to control females. The apical region of the vitellarium contained almost all immature oocytes and each of them had a few trophocytes enclosed within a follicular epithelium. The development of these

oocytes in some ovarioles was not normal as compared to the other ovarioles of the same ovary. However, most of the eggs in the middle portion of the vitellarium were normal. But in few cases, the young ooctyes showed slow development although their nutritive cells were exhausted completely (Plate-XVI, Fig. A). The ooplasm of these oocytes contained small sized vacuoles at the centre and the follicular epithelium was thin as compared to control. The number of these developing oocytes or chorionating eggs was less as compared to the control. In the posterior region of the vitellarium, most of the eggs were fully developed but their number was less as compared to the control. Some of the eggs in this region were smaller in size and the deposition of the yolk granules was poor as compared to the control. In few ovarioles, some malformed oocytes were also observed where no follicular cells were found, the formation of chorion was incomplete and these eggs were in disintegrating state (Plate-XVI, Fig. D). The lumen of the lateral oviducts was reduced slightly and the layer of the longitudinal and circular muscle fibres became thick as compared to the control. The topical application of lower concentrations of dichlorvos (i.e. 0.08 and 0.06%) on the 5th instar larvae showed no cellular damage in the ovaries of the females that emerged from such stock.

24.2. Effects on Ovaries of Adult Females Following Topical Application of Dichlorvos on 6th Instar Larvae of *D. obliqua* Wlk.

The males and females which emerged from the topically treated 6th instar larvae (one day old) with 0.4, 0.2, 0.1, 0.08 and 0.06% dichlorvos were kept in ten pairs.

The ovaries of the two days old affected females which emerged from the treated larvae after the topical application of 0.4, 0.2 and 0.1% dichlorvos were short in size as compared to that of the control (Plate-XVI, Fig. G & H). The shape of the germarium and the vitellarium was normal but their length was reduced proportionately as compared to control. In some ovarioles there was formation of loop. The size of the terminal bundle was reduced as compared to that of the

control. In some cases the length of the ovarioles varied within the same ovary. The size of the terminal bundle of the ovary was short as compared to that of the control. The size of the section of the vitellarium having matured oocytes became short, whereas, the length of the portion having immature oocytes was increased as compared to unaffected (control) females. The number of the chorionated eggs in an ovariole was comparatively less and the distribution of these eggs were not uniform as compared to that of the control. Further, the bursa copulatrix became slender, short and delicate. In some cases wrinkles appeared in the accessory glands due to the lack of their contents. The topical application of the lower concentrations viz. 0.08 and 0.06% of dichlorvos on the larvae did not show anatomical effect in the ovaries of the emerged females.

The cellular structure of the ovarioles of the affected females which emerged from the treated larvae following the topical application of 0.4, 0.2, 0.1 and 0.08% concentrations had only few anomalies. The cellular organization of the germarium was intact but the number of primordial germ cells was reduced as compared to control-I. In the apical portion of the vitellarium, large number of immature oocytes was present which showed normal development but in some oocytes, the growth was slow. In some females, the apical portion of vitellarium had some ooblasts where the differentiation between the trophocytes and oocytes was not clear. The number of these immature oocytes was higher as compared to control females. In the middle portion of the vitellarium, most of the eggs had normal deposition of yolk granules and the secretion of chorion was almost complete. However, in some eggs the accumulation of yolk granules was not normal. Some previtellogenic oocytes developed an empty space inside the ooplasm, though their accompanying trophocytes were still much bigger. In the posterior region of the vitellarium, a gap between the egg surface and ovariole wall was observed (Plate-XVI, Fig. B). The number of chorionated eggs was less as compared to the control females. The epithelial layer of the lateral oviducts was thin and consisted of small cubical cells. Their nuclei were comparatively less distinct and less granulated than control. The topical application of the lowest concentration (0.06%) of dichlorvos did not produce any histological changes in the ovaries of the affected females.

25.1. Effects on Ovaries of Adult Females Following Topical Application of Furadan on 5th Instar Larvae of *D. obliqua* Wlk.

Following the topical application of 0.08, 0.06 and 0.04% furadan on the 5th instar larvae of *D.obliqua*, the size of the ovaries of emerged females reduced drastically as compared to that of the control females (Plate-XVII, Fig. E, F, & G). The size of the germarium and the immature part of the vitellarium (ovariole) was also reduced proportionately and in some ovarioles even the distinction between germarium and vitellarium was obscured. The bundle of terminal filaments of the ovary was much shorter and thinner as compared to that of the control. In few cases the ovarioles terminated freely without filaments, in others, the free ends were highly filamentous (Plate-XVII, Fig. C). At some points, along the length of the ovarioles there was lack of eggs resulting in narrow empty spaces. The number of eggs per ovariole was reduced significantly as compared to unaffected (control) females. The length of the ovarioles in the same ovary remarkably varied. The size of the lateral oviducts, common oviduct and bursa copulatrix became reduced and the latter was less sclerotized when the larvae were treated with 0.08% furadan. On the contrary, the topical application of 0.06 and 0.04% furadan on these larvae caused only a slight effect on the size of the bursa copulatrix. Although, the size of the spermatheca was unchanged, its glandular portion was much coiled. The size of the accessory glands was reduced proportionately and in some cases wrinkles appeared due to lack of contents. However, the topical application of 0.02 and 0.01% furadan did not produce any anatomical abnormality in the ovaries of the emerged females.

The histological study of the ovaries of emerged females from the 5th instar larvae topically treated with 0.08, 0.06 , 0.04 and 0.02% furadan reveals that the nature of the damage in all the ovaries was almost identical, however, the degree of such damages was dose based. The number of primordial germ cells in the germarium was reduced as compared to unaffected (control-I) females. The upper portion of the vitellarium contained less number of immature oocytes which were comparatively smaller in size. In some ooblasts the differentiation between the

trophocytes and the oocytes was not clear. The follicular epithelium of these oocytes was thin and made-up of loosely arranged cuboidal cells. In the middle region of the vitallarium, some of the malformed intercalary oocytes developed necrosis. The follicle cells of these eggs had shrinkage. Possibly these cells had undergone degeneration (Plate-XVII, Fig. B). In some cases, the small, narrow empty spaces of the ovarioles were filled with a crowded mass of cells having elongated nuclei. The deposition of yolk granules was not normal. The cytoplasm, in few oocytes, showed clear-cut separation as the central rounded mass become separated from the peripheral mass by a wide space, the two masses showing completely different consistency and staining property (Plate-XVII, Fig. B). In the posterior part of the vitellarium, the chorionated eggs were widely separated from the ovariole wall. In some cases, the chorion was bulged out noticeably from the egg surface. The architecture of the ooplasm of a few eggs did not resemble with either that of normal chorionating or a chorionated eggs. The follicle cells of malformed oocytes had undergone shrinkage, and moderate to excessive gaps developed between the cells. The cytoplasm of such oocytes showed an abnormal staining property. The longitudinal muscle fiber layer and the circular muscle fiber layers of the lateral oviducts were comparatively less thick and the size of the lumen was reduced as compared to the unaffected females. The topical application of the lowest concentration (0.01%) of furadan did not produce any histological damage in the ovaries of the females that emerged from the treated larvae.

25.2. Effects on Ovaries of Adult Females Following Topical Application of Furadan on 6th Instar Larvae of *D. obliqua* Wlk.

The anatomical structure of the ovaries of the females which emerged following the topical application of 0.08, 0.06 and 0.04% furadan on these larvae revealed reduction in the size of the ovaries (Plate-XVII, Fig. H-I). The size of the germarium was reduced remarkably, whereas the length of the immature part of the vitellarium was increased leaving a short mature part of the vitellarium. At few places along the length of the ovariole, many eggs appeared as clumsy aggregated

masses, whereas, at some other points there was lack of eggs resulting in narrow empty spaces, resulting in uneven distribution of eggs. The number of matured eggs was also less as compared to that of the control. The bursa copulatrix became delicate and less sclerotized as compared to that of the control. The size of the accessory gland was reduced proportionately and their reservoirs were comparatively less sclerotized. The topical application of the lower concentrations (viz., 0.02 and 0.01%) of furadan could not produce damage in the anatomical structure of the ovaries of the emerged females (affected). On the histological examination of the ovaries of emerged females following the topical application of 0.08, 0.06 and 0.04% furadan on these larvae, the number of primordial germ cells in the germarium were seen reduced as compared to unaffected (control) females. The apical portion of the vitellarium contained less number of immature oocytes as compared to unaffected females. The development of these oocytes were not uniform and some oocytes remained as underdeveloped (Plate-XVII, Fig. D). The trophocytes of some previtellogenic or highly immature oocytes were loosely arranged. In some cases, the differentiation between trophocytes and oocytes were not clear. In the middle portion of the vitellarium, the individuality of the compactly arranged follicle cells could hardly be ascertained in some non-chorionated oocytes. The trophocytes had almost been used up even though the staining property of these oocytes indicate their extremely young conditions. In some previtellogenic oocytes small empty spaces inside the ooplasm had developed, though their accompanying trophocytes were still much bigger (Plate-XVII, Fig. A). The posterior most part of the vitellarium contained comparatively less number of chorionated eggs and showed a noticeable gap between the egg surface and ovariole wall. The ooplasm of a few chorionated egg showed complete splitting at the periphery. Some of the chorionated eggs had very small amount of yolk protein in the ooplasm. In some cases, a central mass of ooplasm had become completely separated from the peripheral mass by a small gape. These two masses showed completely different staining property. The ooplasm of the chorionated eggs of some individuals showed differential growth pattern including the accumulation of yolk protein spheres. The thickness of the longitudinal and circular muscle fibers of the lateral oviduct were not uniform. Moreover, the epithelium of the lateral oviducts was thin and their cells as well as their nuclei were less granulated as compared to that of the control. The

lumen of the lateral oviducts was broader as compared to the lumen of the common oviduct. The epithelium of spermatheca was internally lined with a dark brown intima which comparatively send out less number of processes projecting into the lumen as compared to the control, while in some other cases, none of these processes could unite with each other and the formation of a reticulum of internal processes in the lumen could not be observed. The topical application of the lower concentrations of (0.02 and 0.01%) furadan showed no cellular damage in the ovaries of the emerged females.

26.1. Effects on Ovaries of Adult Females Following Topical Application of Carbaryl on 5th Instar Larvae of *D. obliqua* Wlk.

The males and females which emerged from the topically treated 5th instar larvae (one day old) by 0.15, 0.1, 0.08, 0.06 and 0.04% concentrations of carbaryl were kept in ten pairs after two days following emergence.

Anatomically the ovaries of two days old females which emerged from the 5th instar nymphs following the topical application of 0.15 and 0.10% carbaryl were smaller in size than that of the control females (Plate-XVIII, Fig. E & F). Although, the distinction between the germarium and the vitellarium was very clear, the length of the terminal filaments was increased slightly and these were more twisted as compared to the control (Plate-XVIII, Fig. C). Furthermore, each ovariole was more profusely and densely covered by the trachea branches and fat body as compared to that of the control. In some ovarioles there was uneven growth of the oocytes, in others there was accumulation of chorionated eggs at the distal end and a formation of a convoluted mass near the oviduct took place (Plate-XX, Fig. C). The formation of loop occurred in one or two ovarioles(Plate-XII, Fig. D). The lateral oviducts became slightly more elongated as compared to that of unaffected (control) females. The size of the bursa copulatrix was reduced slightly in case of ovaries affected with 0.15% concentration. Following the application of the rest of the concentrations (viz.

0.08, 0.06 and 0.04%) on the 5th instar larvae, the anatomical condition of the ovaries of emerged females remain similar to those of control females.

The ovaries of the emerged females following the topical application of 0.15, 0.10 and 0.08% carbaryl on the 5th instar larvae developed some marked changes in their cellular structure. The primordial germ cells in the germarium were normal but their number was less as compared to control females. The apical portion of vitellarium had large number of immature oocytes as compared to that of the control. The follicle cells of some of these oocytes were loosely arranged leaving some small spaces between them. The density of ooplasm was thin and the cytoplasm of some trophocytes was less granulated as compared to that of the control. The middle portion of the vitellarium contained comparatively less number of matured oocytes in comparison to the unaffected females. The development of some of the oocytes in this region was not normal as compared to the other oocytes of this region, although the accompanying trophocytes of the under developed oocytes were almost exhausted. The formation of chorion around the oocytes of this region had almost completed. In the posterior most part of the vitellarium a gap developed between the egg surface and ovariole wall (Plate-XVIII, Fig. B). In some eggs the deposition of yolk spheres were very less and the ooplasm was condensed and broken into many parts. The shape of these eggs were irregular (Plate-XVIII, Fig. A). The cellular structure of lateral oviducts was unchanged but the size of its lumen was reduced as cornpared to control. The topical application of lower concentrations (i.e. 0.06 and 0.04%) of carbaryl on the 5th instar nymphs did not affect the histological organization of the ovaries of the emerged females.

26.2. Effects on Ovaries of Adult Females Following Topical Application of Carbaryl on 6th Instar Larvae of *D. obliqua* Wlk.

The topical application of the highest concentrations of carbaryl (0.15%) on the 6th instar larvae led to only a few anatomical disorders in the ovaries of the emerged females. But the topical application of the rest of the concentrations (i.e.

0.10, 0.08, 0.,06 and 0.04%) had no effect. The size of the ovaries after the topical application of 0.15% carbaryl on the 6th instar larvae was reduced remarkably (Plate-XVIII, Fig. I). All other anatomical features of the ovaries were like those of control females except the number of eggs in the ovarioles was comparatively reduced.

The histological aberrations of the ovaries of the emerged females (2 days) following the topical application of 0.15 and 0.10% carbaryl on the 6th instar larvae revealed normal cellular organization of the germarium and that of the primordial germ cells. The immature part of the vitellarium had a number of immature oocytes as compared to that of the control and the development of these oocytes was neither uniform nor in a linear order (Plate-XVIII, Fig. D). The trophocytes were large and irregular in shape. However, in some cases, the nutritive cells were comparatively smaller in size and contained less granulated cytoplasm. The follicular epithelium around these oocytes were loosely arranged. The middle portion of the vitellarium contained less number of fully matured and chorionating eggs as compared to that of the control. In some eggs the deposition of the yolk granules was reduced and the development of the oocytes was not normal though their accompanying trophocytes were exhausted. In the posterior region some of the eggs were malformed in which the cytoplasmic mass of the oocytes was broken into many globular parts. The number of chorionated eggs was less as compared to that of control females. The topical application of the lower concentrations (0.08, 0.06 and 0.04%) of carbaryl on the 6th instar nymphs did not produce any histological aberrations in the ovaries of the emerged females.

27.1. Effects on Ovaries of Adult Females Following Topical Application of Aminocarb on 5th Instar Larvae of *D. obliqua* Wlk.

The males and females which emerged from the topically treated 5th instar larvae (one day old) by 0.25, 0.20, 0.15, 0.10 and 0.08% aminocarb were kept in ten pairs after two days following emergence.

The anatomical picture of the ovaries of emerged females after the topical application of 0.25% aminocarb on the 5th instar larvae developed a few abnormalities as compared to that of control females. Generally in most of the cases, the size of the ovaries was reduced slightly (Plate-XIX, Fig. F), however, in some severely affected females, the size of the ovaries was reduced drastically as compared to control (Plate-XIX, Fig. E & H). The shape and size of the germarium was normal. The distinction between the germarium and the vitellarium was clear. The length of the vitellarium was comparatively unchanged, whereas, these ovarioles were narrower and contained less number of chorinonating and chorionated eggs as compared to the control. In few ovarioles, a narow empty space was developed due to the lack of eggs (Plate-XX, Fig. E), while in certain others, more than one eggs were grouped in a single egg chamber and formed a compound egg chamber (Plate-XIX, Fig. C). In some cases a pouch like structure developed at the junction of the lateral oviducts and the ovarioles, due to the accumulation of chorionated eggs (Plate-XIX, Fig. C). The size of the bursa copulatrix was also reduced slightly and it was comparatively less sclerotized than the control. The spermathecal gland became more coiled, however, its shape and size remained unchanged. However, the topical application of the rest of the concentrations viz. 0.20, 0.15, 0.10 and 0.08% aminocarb did not produce any change in the anatomical structure of the ovaries of the emerged females.

The histological picture of the ovaries of the emerged (affected) females following the topical application of 0.25, 0.20 and 0.15% aminocarb on the 5th instar larvae caused some cellular anomalies. Although, the cellular organization of the germarium was unchanged, the number of trophocytes was less in proportion to oocytes. The apical portion of the vitellarium contained immature oocytes which showed less development as compared to that of the control. In few ovarioles the immature oocytes in the apical portion were comparatively smaller in size and arranged with wide gap unlike that of the control (Plate-XIX, Fig. D). In the middle portion of the vitellarium, the cytoplasm in most of the oocytes was smooth but in few cases a central rounded mass developed in the ooplasm which was distinctly separated from the main peripheral mass with a wide space. In few oocytes, an empty space inside the ooplasm was developed, while in some others, the ooplasm

had small vacuoles (Plate-XIX- Fig. B). The follicular cells had undergone shrinkage and the formation of chorion was incomplete. In the posterior most part of the vitellarium, most of the eggs were mature with complete chorion formation but the size of these eggs were comparatively smaller and the number was less as compared to the control. The wall of the lateral oviducts was more thick at the site where the two oviducts converge into the common oviduct, resulting in to a narrower lumen as compared to the control. The topical application of lower concentrations (0.1 and 0.08%) of aminocarb on the 5th instar larvae did not affect the ovaries of the emerged females.

27.2. Effects on Ovaries of Adult Females Following Topical Application of Aminocarb on 6th Instar Larvae of *D. obliqua* Wlk.

The males and females which emerged from the topically treated 6th instar larvae (one day old) by 0.25, 0.20, 0.15, 0.10 and 0.08% aminocarb were kept in ten pairs after two days following emergence.

The anatomical picture of the ovaries of emerged females after the topical application of the highest concentrations (0.25%) of aminocarb on the 6th instar nymphs developed some abnormalities. The size of the ovaries of the affected females was reduced slightly (Plate-XIX, Fig. G & I). The terminal filaments of the ovaries were comparatively longer than that of the control. The germarium was well developed and the immature part of the ovariole became enlarged. The shape of the lateral oviducts were unchanged but its length increased slightly as compared to the control. The topical application of rest of the concentrations (viz. 0.20, 0.15, 0.10 and 0.08%) of aminocarb was ineffective in producing any anatomical aberration.

The histological picture of the ovaries of the emerged females after the topical application of 0.25 and 0.20% concentrations on the 6th instar larvae had only a mild damage in the cellular structure, which were mostly localized in the vitellarial part of the ovariole. The development of oocytes in most of the ovarioles were normal and

they were arranged linearly. But in few cases, the development of these oocytes were slow and they were not arrangement linearly (Plate-XIX, Fig. A). The trophocytes in these oocytes were enlarged, loosely arranged and their accompanying cells were absent. The middle portion of the vitellarium of the affected ovarioles contained less number of oocytes as compared to that of control females. In some mature eggs, the density of the ooplasm at the periphery was thin and it seemed sharply divided into a cortex and medulla. The posterior region of the vitellarium had less number of chorionated eggs as compared to that of the control. Some small but chorionated eggs were located between the large eggs, which still had prominent follicle cell. The topical application of lower concentrations (i.e. 0.15, 0.10 and 0.08%) of aminocarb did not affect the histological nature of the ovaries of the emerged females.

V-DISCUSSION

1. Mortality

The effects of organophosphate and carbamate insecticides on 4th and 5th instar nymphs of *Dysdercus cingulatus* are varied. The topical application of dilute (sublethal) concentrations of furadan (carbamate) caused higher mortality in comparison with similar as well as higher concentrations of other selected organophosphate and carbamate insecticides applied on the 4th and 5th instar nymphs. Generally, the earlier nymphal stage (4th instar) was more susceptible than the later stage (5th instar). Furr and Calhoun (1952) found several insecticides more toxic to the third instar than the fourth instar larvae of fall army worm *Laphygma frugiperda*

Mcphersan *et al.* (1956) applied DDT, BHC sulphur mixture and endrin topically on the larvae of *Heliothis zea* and *Heliothis virescens* (Fab) and concluded that the percent control of the larvae decreased as the larval weight and age increased. The observations of Rani and Osmani (1982) further confirmed the findings of Mcphersan *et al.* (1956) by recording that the LD_{50} value of cyphenothrin for 5 day old males and females of *Dysdercus cingulatus* varied because of the difference in their body weight and size. Similar results were also recorded by Eldefrawn *et al.* (1964) with the larvae of Egyptian cotton leafworm *Prodenia litura* Fab. In the present investigation, the topical application of 0.01% dichlorvos on 4th instar nymphs of *D. cingulatus* showed 22% more nymphal deaths as compared to the topical application of the same concentration on the 5th instar nymphs. Further, the topical application of 0.0025% carbaryl on 4th instar nymphs showed 18% more nymphal loss as compared to the 5th instar treatment. These differences in mortality between the two treated nymphal stages can also be due to the differences in their body weights. According to Kabir and Chaudhury (1970), who tested five organophosphate insecticides against the 3rd instar nymphs and adults of *D. koenigii*, the nymphal stages were more susceptible to these insecticides as compared to adults, with regard to their mortality. Out of these insecticides azodrin was most toxic, followed by bidrin > diazinon > dimecron > birlane to the third instar nymphs.

In the present investigation the topical application of 0.001% furadan on 4th instar nymphs gave 43 and 16% more nymphal mortality as compared to the same concentration of ethion and acephate, respectively. Furthermore, when the same concentration (0.001%) of furadan was applied on 5th instar nymphs of *D. cingulatus* the toxic effect was less pronounced as the nymphal mortality was only 32 and 17% more as compared to the same concentrations of ethion and acephate, respectively. Furthermore, the toxicity of 0.001% furadan to the 4th instar nymphs was 14% more as compared to that of the treated nymphs of the 5th instar. Khowaja *et al.* (1995) also recorded the similar difference of mortality (14%) between 4th and 5th instar nymphs of *D. cingulatus* after the topical application of same concentration of (0.001%) temik (aldicarb). The topical application of 0.004% aminocarb on the 4th instar nymph of *D. cingulatus* showed 32 and 9% more nymphal loss as compared to the application of the same concentration of dichlorvos and ethion (organophosphates) respectively, whereas, the topical application of the same concentration (0.004%) of aminocarb on the 5th instar nymphs resulted in only 27 and 8% more death than following the application of the same concentration of dichlorvos and ethion, respectively, on the same instar. Further, the topical application of 0.002% acephate on the 4th instar nymphs of this species caused 19% more nymphal deaths as compared to the same concentration of carbaryl and aminocarb (carbamate), respectively. However, the treatment of the 5th instar nymphs with 0.002% acephate showed 18 and 12% more nymphal loss as compared to the application of same concentration of carbaryl and aminocarb, respectively. Similarly, the total nymphal loss up to adult emergence after the topical application of 0.001% acephate on 4th instar nymphs was 30 and 14% higher as compared to the same concentrations of carbaryl and aminocarb, respectively. Whereas the treatment of the 5th instar nymphs with the same concentration (0.001%) of acephate resulted in only 15 and 8% more nymphal loss as compared to the same concentration of carbaryl and aminocarb, respectively. On the basis of the above results which showed varied levels of mortalities following the application of the presently tested insecticides, the toxicity can be graded as furadan > acephate > dichlorvos > carbaryl > ethion > aminocarb. Kumar *et al.* (1976) studied the comparative toxicity of nine insecticides for the control of *Dysdercus koenigii* Fabr.

and recorded the performance in order of toxicity as Baygon > Endrin > Sumithion > Ekatox > Rogor > Thiodan > Anatox > DDVP.

Similarly, the effects of the selected insecticides on *Diacrisia obliqua* also varied and the topical application of the diluted concentrations (sublethal) of furadan (carbamate) caused higher mortality in comparison to the similar as well as higher concentrations of the other insecticides. Nigam (1970) recorded that out of the seven tested insecticides belonging to both carbamate and organophosphate groups (viz., propoxur, zectran, sumithion, amidithion, phosphamidon, dimethoate and DDT) against the sawfly larvae, the carbamate insecticides (viz., propoxur and zectran) were more toxic than organophosphate insecticides. He reported that the early larval stage (5th instar) was more susceptible than the later larval stage (6th instar) as is the result in the present observation on *D. cingulatus*. In the present study, the topical application of 0.08% furadan on the 5th instar larvae of *D. obliqua* resulted in 17% higher larval death as compared to the topical application of same concentration on the 6th instar larvae. Further, the topical application of this concentration of furadan (0.08%) on the 5th instar larvae of *D. obliqua* produced 52, 43 and 23% more larval loss up to the adult emergence as compared to the topical application of the same concentration of ethion, dichlorvos and acephate, respectively. However, the total larval loss up to the adult emergence following the topical application of 0.08% furadan on 6th instar larvae was 42, 33 and 19% more as compared to the application of the same concentration of ethion, dichlorvos and acephate, respectively. Again it suggests that application of the aforesaid insecticides leads to higher toxicity when applied on the younger larval stages than on the older ones. According to Mandal and Senapati (1989) the treatment of the 5th instar larvae of *Diacrisia obliqua* with 0.05% active ingredient (a.i.) of endosulfan produced 100% mortality within 24 hours. However, 0.04 and 0.03% active ingredient (a.i.) produced 96.7 and 93.4% mortality respectively, at 72 hours to the same stage larvae. The topical application of 0.1% acephate on 5th instar larvae of *D. obliqua* caused 45 and 4% more mortality as compared to the same concentration of aminocarb and carbaryl, respectively. Whereas the topical application of the same concentration of acephate (0.1%) on the 6th instar larvae resulted in only 27 and 2% more larval loss as compared to the application of the

same concentration of aminocarb and carbaryl, respectively, on the same instar. Markin *et al.* (1978) tested toxicity of carbaryl, trichlorfon and acephate at two different droplet sizes against *Orgyia pseudosugata, Choristoneura occidentalis* and observed that the small droplets of carbaryl and trichlorfon caused higher mortality of both tested insects, whereas, small droplets of acephate caused higher mortality in *C. occidentalis.* The results from the present observations clearly indicate the remarkable variation of relative performance of the different selected insecticides and that the early larval stage was more susceptible to the presently used insecticides as compared to the later larval stage. Gargav and Katiyar (1971) tested six pesticides in the laboratory against the 3rd instar larvae of *D. obliqua* and recorded 88% mortality of the tested larvae following the application of 0.1% carbaryl. However, in the present investigation on the same species the topical application of 0.1% carbaryl on 5th instar larvae caused only 49% mortality which was 39% less as compared to 3rd instar treatment. This observation, therefore, further strengthens the fact that the early larval stages are more susceptible than the later larval stages. The total larval mortality after the topical application of 0.06% acephate on the 5th instar larvae of *D. obliqua* was 11% more as compared to the application of similar concentration of carbaryl on the same instar, whereas, it was 19% less as compared to the same concentration of furadan. Further, the topical application of 0.06% acephate on the 6th instar larvae showed only 6% more deaths as compared to the same concentration of carbaryl, whereas, mortality was 19% less as compared to the same concentration of furadan. The topical application of 0.2% dichlorvos on the 5th instar larvae of *D. obliqua* resulted in 10% higher larval loss as compared to the same concentration of aminocarb, however, this difference was only 8% when the 6th instar larvae were subjected to the treatment. Tanton and Khan (1978) also observed that fenitrothion at 20-6300 µg a.i./g larval fresh body weight of *Paropsis atomaria* caused more mortality to 2nd and 4th instar larvae than the same dose of aminocarb. In the present observation, the topical application of 0.1% carbaryl on the 5th instar larvae produced 30 and 15% more larval death up to adult emergence as compared to the same concentration of ethion and dichlorvos, respectively. But the topical application of the same concentration (0.1%) of carbaryl on 6th instar larvae could produce only 22 and 9% more larval loss as compared to the similar concentration of ethion and dichlorvos, respectively. According to Singh

et al. (1978) the feeding of treated leaves with carbaryl to the young larvae of *D. obliqua* showed 33.9 and 31% more mortality as compared to 0.05% phosalone and 0.05% leptophos, respectively. Being of low mammalian toxicity and higher insecticidal activity, Gargav and Patel (1973) have recommended carbaryl out of different tested insecticides as a good insecticide for the control of *Nymphula depunctalis.* Kotikal and Devaiah (1988) also tested the toxicity of 0.1% carbaryl, dichlorvos, monocrotophos and endosulfan by spraying on plants against *D. obliqua* and concluded that all the tested insecticides were toxic to all larval instars of this arctiid. Similarly, the sprays of fenitrothion (organophosphate) and carbaryl (carbamate) gave moderate control of young and mature larvae of *Spilosoma obliqua* (Sidhu and Dhawan 1980), whereas, Grewal *et al.* (1978) observed that out of different tested insecticides, quinalphos at 0.05% was most effective against the full grown larvae of *D. obliqua* which gave 98.9% mortality. Ahmad *et al.* (1985) tested 3 pyrethroid insecticides against the 4th instar larvae of *Spodoptera littoralis* and concluded that deltamethrin was the most effective insecticide followed by floucythranate > cypermethrin. Similarly, in the present investigation all the tested insecticides as mentioned earlier (organophosphate and carbamate) showed remarkable variation in their toxicity. Furadan (carbamate) was the most toxic insecticide against both 5th and 6th instar larvae followed by carbaryl > ethion > dichlorvos> aminocarb > acephate.

2. Longevity

Besides the acute toxicity produced by the present chemicals, the biology and physiology of the survived insects (*Dysdercus cingulatus* and *Diacrisia obliqua*) were also affected by their sublethal dosages. Some earlier reports suggest that the application of sublethal doses of insecticides enhance the longevity of the survived insects as compared to the control (Knutson, 1955; Katiyar and Lemonde, 1972; Parker *et al.,* 1976; Khowaja *et al.,* 1991; '92; '93; '94; Abo-Elghar *et al.,* 1972). On the other hand, other workers concluded that the application of sublethal doses of insecticides reduced the longevity of the survived insects (Adkisson and Wellso, 1962; Ridgway *et al.,* 1965; Georghiou, 1965; Moriarty, 1969; Bariola and Lindquist, 1970; Haynes, 1988; Mackenzie and Winston, 1989). The present

findings on *D. cingulatus* and *D. obliqua* also prove that the topical application of sublethal concentrations of all the selected insecticides (organophosphate and carbamate) except furadan enhance the longevity of all the stages of survived treated insects. The topical application of 0.006% ethion on 4th instar nymphs of *D. cingulatus* showed average enhancement of nymphal duration by 23 and 26% of the 4th and 5th instar, respectively, as compared to the control. The topical application of 0.003% monocrotophos on 4th instar nymphs of this species resulted in the prolongation of 4th and 5th instar nymphal duration by 41.86 and 50.90%, respectively, (Khowaja *et al.*, 1992). Furthermore, the topical application of the same concentration of ethion (0.006%) on 5th instar nymphs resulted in the enhancement of average nymphal duration which was 37.2% higher than the control. However, the topical application of 30 ppm monocrotophos on the 5th instar nymphs of *D. cingulatus* enhanced the nymphal duration by 43.1% as compared to the control (Khowaja *et al.*, 1994). The life span of the adult males emerged from 0.006% ethion treated 4th instar nymphs was increased by 31.9%, whereas, the longevity of the adult males emerged from 5th instar treated nymphs following the application of the same concentration of ethion was increased by 40.9% as compared to the control. However, Khowaja *et al.* (1994) reported 26.5% enhancement in the longevity of the adult males of *D. cingulatus* emerged from the 5th instar treated nymphs with 30 ppm monocrotophos as compared to the control. Similarly, the longevity of the male *D. cingulatus* emerged from the 4th instar treated nymphs with 0.008 µg cythion was enhanced by 38.9% as compared to the control (Khowaja *et al.*, 1991). The increase in the longevity following the exposure to the insecticides was also reported by other workers. According to Ouye and Knutson (1957) the longevity of adult house flies, *Musca domestica* obtained from the larvae treated with 2 ppm malathion was 82% more as compared to those which emerged from untreated larvae. The topical application of malathion on 24-48 hrs old *Menochilus sexmaculata* resulted in greater life span of flies receiving the highest dose (Parker *et al.*, 1976). The longevity of the female German cockroaches *Blattella germanica* (L) increased linearly with increasing sublethal doses of chlorpyrifos (Abd-Elghafar and Appel, 1992). Ball and Su (1979) reported that *Diabrotica virgifera* females treated topically with sublethal doses of carbofuran and carbaryl lived significantly longer than the untreated females (control).

On the contrary, in the present investigation, the females that emerged from the 4th instar treated nymphs with selected higher sublethal concentrations of furadan (carbofuran) and carbaryl lived shorter than the unaffected females. The topical application of 0.001% furadan on the 4th instar nymphs of *D. cingulatus* reduced average nymphal duration by 6.44% as compared to the control. Whereas the longevity of the male adults emerged from the 4th instar treated nymphs was reduced by 14% as compared to the control. However, the longevity of adult males, emerged from the 5th instar treated nymphs following the topical application of same concentration of furadan (0.001%) was reduced by 11.8% as compared to the control. Adkisson and Wellso (1962) also observed shortening of longevity in adults of *Pectinophora gossypiella* Saunders after the treatment with low doses of DDT. The exposure to various sublethal concentrations of diazinon once or repeatedly, reduced the longevity of worker bees, *Apis mellifera* (Mackenzie and Winston, 1989). According to Hamilton and Schal (1990) the topical application of LC_{10}, LC_{20} and LC_{60}s of chlorpyrifosmethyl on 2 day old female German cockroaches *Blattella germanica* (L) reduced their longevity. Abd-Elghafar and Appel (1992) observed that the longevity of male German cockroaches *B. germanica* (L) declined linearly and the LD_{50} value of cyfluthrin and hydramethylnon decreased the male longevity by 52 and 81%, respectively, as compared to the control.

Similarly, the topical application of different concentrations of the selected insecticides in the present investigation also enhanced the life span of the larval, pupal and adult stages of *Diacrisia obliqua* but this enhancement varied with different insecticides. The topical application of 0.1% acephate on the 5th instar larvae of *D. obliqua* extended larval duration by 22.5%, pupal duration by 27.9% and those of the adult males and the females by 18.91 and 13.9%, respectively, as compared to their respective controls. The maximum enhancement in the larval, pupal durations and adult male and female life span was recorded in case of 0.25% aminocarb following its application on the 6th instar larvae of *D. obliqua* which was 24.7, 37.9 and 29.9 and 14.96%, respectively, as compared to their corresponding controls. The longevity of the 6th instar larvae and pupae of *Spodoptera litura* enhanced by 44.05 and 26.2%, respectively, as compared to the control following the topical application of 10,000 ppm cythion per 6th instar larvae. Whereas the

average longevity of adult males and females emerged from the 6th instar treated nymphs was reduced by 6.01 and 10.41%, respectively, as compared to the control (Khowaja *et al.,* 1993). According to Katiyar and Lemonde (1972) insecticides accelerate anti-acetylcholinesterase activity and correspond to greater prolongation of the larval period. Organophosphate insecticides were also reported to inhibit the hydroxylation process of some steroids (Conney *et al.,* 1966). Ecdysone is a steroid which plays an important role in the moulting process in insects. If insecticides in question block the hydroxylation process, then there may not be enough of this hormone necessary for the moulting process. This may cause the prolongation of the larval period. Sublethal doses of chlorpyrifosethyl significantly depress the movement (Abd-Elghafar *et al.*, 1991) and probably respiration in the adult German cockroaches. Movement and possibly metabolism declined with increasing doses and might account for increasing the female longevity (Abd-Elghafar and Appel, 1992). Luckey (1968) reported that the growth rate of house crickets *Acheta domesticus* (L) (Orthoptera: gryllidae) increased when they were treated with sublethal concentrations of 14 pesticides. He explained this phenomenon through his "hormoligosis hypothesis" suggesting that sublethal quantities of any stressing agent will be stimulatory to an organism by providing it with increased sensitivity to respond to changes in its environment and increased efficiency to develop new or better systems to fit in a suboptimum environment". In the present investigation, the enhancement of longevity by exposure to all the selected insecticides (acephate, ethion, dichlorvos, carbaryl and aminocarb) except furadan concur with this theory. Results with furadan, however, directly contradict the "hormoligosis hypothesis" because longevity of all the affected stages of *D. cingulatus* declined with increasing concentrations. Like other type II pyrethroids, cyfluthrin increase respiration by inducing sustained muscular contractions (Cornwell, 1968). Increased respiration and the release of a paralysis inducing stress factor may account for the decrease in longevity of cockroaches treated with sublethal concentrations of cyfluthrin (Abd-Elghafar and Appel, 1992).

3. Moulting disorders

Beside the increase in the duration of the larval, nymphal as well as the adult stages, following the treatment with different concentrations of the presently selected insecticides, a remarkable percentage of abnormal adult emergence and subsiquent death during emergence was also noticed in most cases. However, both abnormal emergence and death during larval or nymphal moulting were resulted only by the application of the higher concentrations of the presently used insecticides than by their lower concentrations. The degree of mortality at the larval or nymphal moulting or the percentage of malformed adults emerged from the affected insects were almost uniform by the application of any of the selected insecticides of the present investigation. The abnormal adults were characterized with deteriorated or incomplete or wrinkled wings, abdomen, antennae and legs in different degrees. These abnormal adults were sluggish and were unable to take food and finally died within a few days. Earlier, Khowaja *et al.* (1995) reported that the topical application of 10, 8, 6, 4 and 2 ppm temik (carbamate) per 4th instar nymph of *D. cingulatus* resulted in emergence of 7.1, 6.2, 4.7, 3.1 and 2.0% adults with malformed wings, respectively, as compared to the control. The topical application of the aforesaid concentrations on the 5th instar nymphs resulted in 9.63, 8.17, 6.92, 4.42 and 3.09% adults with malformed wings, respectively, as compared to the control. The abnormal emergence may be either due to the direct effect on the individual epidermal cells or the quantitative paucity and inadequate action of the moulting hormone. The first possibility has been supported in *D. koenigii* (Harwalkar and Nair; 1968) because the nymphs of this species were treated within a day following the previous moult when initiation of mitotic division of epidermal cells under the influence of moulting hormone was affected. Similarly, in the present study of *Dysdercus cingulatus* and *Diacrisia obliqua*, the nymphs and larvae were treated just after 24 hours following emergence when the phase of the active mitotic division in the epidermal cells under the influence of moulting hormone might have been affected. Thus, poor action of moulting hormone may be more convincing for abnormal emergence, because the control of metamorphosis, especially the initiation of the process of building of new cuticle, its growth and moulting depends on the presence of moulting hormone during the entire premoulting period in the

haemolymph where the presence of the insecticide can either inactivate the hormone, or may suppress its release from the glands. However, in the larvae of *Ephestia kuehniella* (Kuzin *et al.*, 1968) lack of moulting hormone has been reported by gamma irradiation and thus pupation was inhibited. Further, Wigglesworth (1959) in *Rhodnius prolixus* reported that in the absence of moulting hormone in the nymphs, the epidermal cells are much attenuated and they remain permanently in resting state and moulting never occurs in such nymphs.

4. Reproduction

The fecundity of the females which emerged from 0.001% furadan treated 4th instar nymphs, was reduced by 48.94% than the control. Whereas the topical application of the same concentration of acephate and ethion on the 4th instar nymphs caused only 15.73 and 2.5% reduction, respectively, in the average egg production of the emerged (affected) females as compared to the control. The fertility of the eggs laid by these affected females emerged from 0.001% furadan treated nymphs was 55.4% less than that of the control. The topical application of the same concentration of acephate resulted in only 18.89% reduction as compared to the control. Further, the treatment of the 5th instar nymphs with 0.001% furadan developed 40.94% inhibition in average egg production of the females which was 36.97 and 31.85% more than the inhibition caused by the topical application of the same concentration of ethion and acephate, respectively. The viability of the eggs laid by such females emerged from furadan treated 5th instar nymphs was 43.17% less than those of the control females, whereas, the application of the same concentration of acephate showed 13.33% reduction in hatching. Likewise the topical application of 0.004% aminocarb on the 4th instar nymphs resulted in 19.44% reduction in the average egg production of the females which was comparatively 15.34 and 5.69% more than the reduction caused by the topical application of the same concentration of dichlorvos and ethion, respectively. The hatchability of the eggs laid by the affected females emerged from 0.004% aminocarb treated 4th instar nymphs was 20.7% less than the control, whereas, the topical application of the same concentration of ethion could inhibit the viability of the eggs by 7.7% as compared to the control. The egg laying by the females that emerged from the 5th

instar treated nymphs with 0.004% aminocarb was reduced by 15.11% as compared to the control. This reduction was 12.07 and 4.19% more than the reduction caused by the topical application of the same concentration of dichlorvos and ethion on the 5th instar, respectively. The fertility of the eggs laid by the females emerged from 0.004% aminocarb treated 5th instar nymphs was decreased by 19.94% than the control, whereas, the treatment of the 5th instar nymphs with 0.004% ethion showed only 8.54% reduction in the fertility of the eggs laid by the affected females. Similarly Khowaja *et al.* (1992) observed that the topical application of 30 ppm monocrotophos on 4th instar nymphs of *Dysdercus cingulatus* resulted in 21.9 and 29.9% reduction in fecundity and fertility of the eggs, respectively, as compared to the control. Whereas the topical application of the same concentration (30 ppm) of monocrotophos on the 5th instar nymphs of *D. cingulatus* could inhibit fecundity and fertility of the females by 18.1 and 22.4%, respectively, as compared to the control (Khowaja *et al.,* 1994). In the present observations, the fecundity and fertility of the females emerged from 0.002% acephate treated 4th instar nymphs was reduced by 21.83 and 25.89%, respectively, as compared to the control. Whereas the topical application of the same concentration on the 5th instar nymphs showed only 13.64 and 19.38% reduction in the average egg production and viability, respectively, as compared to the control. On the contrary, the application of insecticides on insects caused stimulation to the reproduction, such as in *Aphis rumicis* by treatment with rotenone talc (Sun, 1945), houseflies with dieldrin (Afifi and Knutson, 1956), *Musca domestica* with malathion (Ouye and Knutson, 1957), *Diabrotica virgiform* with carbofuran and carbaryl (Ball and Su, 1979), *Geocoris pallens* with DEF, glyphosphate and methomyl (Yokoyama *et al.,* 1984) and *Blattella germanica* with chlorpyrifos (Abd-Elghafar and Appel, 1992). But in most insects exposed to insecticides, fecundity and fertility were adversely affected. Adkisson and Wellso (1962) observed that the pink bollworm, *Pectinophora gossypiella* after the treatment with low doses of DDT produced less number of eggs than the untreated ones. Feeding of small doses of American cyanimid CL-47031 [Cyclic ethylene (diethoxy phosphinyl) = dithioimido - carbonate] to *Anthonomus grandis* caused great reduction in oviposition (Ridgway *et al.,* 1965). Topical application of sublethal doses of 0.3 µg/fly Isolan (1-Isopropyl 3-methyl-5-pyrazolyl demethyl carbonate) to houseflies *Musca domestica* reduced the total egg production by 35.8%, while 0.6

µg (LD_{10}) and 1.0 µg (LD_{30}) doses, respectively, reduced egg production by 43.1 and 77.2% (Georghiou, 1965). Exposure of *Anthonomus grandis* weevil to monocrotophos at 0.8 mg/dish resulted in 23% reduction in egg oviposition of the surviving females during 10-14 days period (Bariola and Lindquist, 1970). The present findings on *D. cingulatus* and *D. obliqua* strengthen the inhibitory effect of the above selected organophosphate and carbamate insecticides on fecundity and fertility. In the present experiments it was recorded that the topical application of 0.08% furadan on the 5th instar larvae of *Diacrisia obliqua* resulted in 39% reduction in the average egg production of the affected females as compared to the control. Whereas the topical application of the same concentration (0.08%) of dichlorvos and acephate on the same stage showed 34.03 and 29.48% less reduction as compared to furadan, respectively. However, the topical application of 0.08% furadan on the 6th instar larvae showed 33% inhibition in the egg production of the affected females which was comparatively 25.86 and 23.95% more than that caused by the application of the same concentration of dichlorvos and acephate, respectively. The fertility of the eggs laid by the affected females emerged from 0.08% furadan treated 5th instar larvae was 40.99% less than that the control, whereas, the topical application of the same concentration of dichlorvos and acephate on the 6th instar larvae produced only 4.08 and 5.9% inhibition in egg hatchability which was 36.91 and 35.09% less as compared to furadan, respectively. However, the fertility of the eggs laid by the emerged (affected) females from the 6th instar treated larvae with 0.08% furadan was reduced by 38.96% than that of the control, whereas, the topical application of 0.08% dichlorvos and acephate showed only 8.75 and 7.01% reduction in hatching, respectively. The topical application of 0.1% acephate on the 5th instar larvae resulted in 8.84% more reduction in the egg production as compared to topical application of the same concentration of aminocarb. Similarly, the topical application of 0.1% of acephate on the 6th instar larvae resulted in 15.01% more inhibition in egg production than that of the same concentration of aminocarb. The hatchability of these eggs laid by the affected females emerged from 0.1% treated 5th instar larvae was 5.55% more than that of the same concentration of aminocarb. Similarly, inhibition in the egg viability of the females emerged from 0.1% acephate treated 6th instar larvae was inhibited 9.62% more as compared to the same concentration of aminocarb. According to Soderstrom and Lovitt (1970), when the

Indian meal moth, *Plodia interpunctella* were exposed to 10 µg and 20 µg malathion there was 18 and 27% decrease in egg production. However, the fertility of the eggs laid by the affected females was reduced by 27 and 15%, respectively. *Menochilus sexmaculatus* females when treated topically with malathion laid fewer eggs than the control (Parker *et al.,* 1976). Similarly, the exposure of 6th instar larvae of *Spodoptera litura* to 10000 ppm cythion (malathion) resulted in 18.23 and 15.97% reduction in oviposition and egg viability of the affected females (Khowaja *et al.,* 1993). Also it is known that landrin, aldicarb, akton and SD-7438 when mixed in the diet of *Tribolium confusum* larvae suppressed egg production by 76.6, 30.9, 73.4 and 74.5% respectively, whereas, the viability of the eggs laid by the affected females was reduced by 97.4 26.2, 69.6 and 75.0%, respectively, as compared to the control (Katiyar and Lemonde, 1972). A significant reduction in the number of oothecae showing much lower life-time fecundity of *Blattella germanica* occurred when these were treated with chlorpyrifos-methyl (Hamilton and Schal, 1990). Further, the application of dose equivalent to LD_{50} of cyfluthrin on *B. germanica* reduced the number of oothecae by 51%, whereas, LD_{50} of hydramethylnon resulted in 89% decrease in oothecae production (Abd-Elghafar and Appel, 1992).

The insects exposed to insecticides can also suffer from inhibition in the fecundity and fertility through the action of these chemicals on organs such as haemocytes and fat body. These organs provide metabolites to the ovaries for the maturation of oocytes. It is generally well established that haemocytes are the sites of metabolism as well as storage of materials transported to them through haemolymph. The role of haemocytes in insect reproduction has also been studied by many workers. Grimstone *et al.* (1967) observed that plasmatocytes in lepidoptera are actively engaged in the uptake of haemolymph by pinocytosis. This activity is very evident in *Rhodnius* and leads to the formation of mucopolysaccharide globules and probably other inclusions (Wigglesworth, 1973). Indeed it has long been assumed that the haemocytes are an active site of protein synthesis. In the cockroach *Nauphoeta* haemocytes take up labelled amino acids and utilize these in the protein synthesis, including production of vitellogenin (Buhlmann, 1974). In *Locusta* X-irradiation of the haemopoetic tissue affects both

the growth of oocytes and the synthesis of haemolymph proteins, effects resembling that of the juvenile hormone deficiency (Goltzene and Hoffmann, 1974).

Schmidt and Williams (1953) demonstrated the importance of a heat sensitive macromolecular (protein) factor in the maturation of sperm in *Hyalophora.* Kambysellis and Williams (1971) found that this factor is necessary for both spermatogenesis and for the maintenance of insect cells in culture. There is evidence that it is synthesized by some haemocytes. Likewise, Landureau and Szollosi (1974) have shown that haemocytes of *Periplaneta* in culture liberate a protein factor that initiate sperm maturation and spermatogenesis in isolated cysts of Saturniids in diapause. This factor is secreted by the hemocytes of both sexes at all stages of the life history.

Zaidi and Khan (1975) studied the changes in total and differential haemocyte counts of *Dysdercus cingulatus* in relation to the reproduction and observed that the females have significantly higher number of haemocytes than the males of the same age group. Furthermore, the total haemocyte count (THC), in the females following emergence decreases initially but later it increases. The first peak of THC occurs on the 4^{th} post emergent day in the females followed by a decrease, then again a small but statistically significant increase in THC occurrs on the 10^{th} post emergent day which later falls down. These two peaks of THC in the females correspond to two preoviposition periods, and falls indicate the periods of maturation of the eggs when general growth and metabolism is expected to be slow. Similarly, the differential haemocyte count (DHC), like THC, varies according to the age of the individuals. In the newly emerged adults the percentage of adipohaemocytes was highest of all the other types of cells and more significantly higher in the males than in the females. It may be explained that lower percentage of adipohaemocytes in the newly emerged females may be due to their utilization in maturation of the ovaries which may begin earlier i.e. in the last nymphal instar. Later, in both sexes, the adipohaemocytes show a falling tendency and after the first reproduction cycle in both sexes, the percentage of these cells is reduced to a greater extent. This decrease in the percentage of adipohaemocytes with respect to the advancing age from the time of emergence may be deduced as utilization of the contents (metabolites) of these cells

by the adults for the maturation of the gonads or in the catabolic activity. The change in the population of the haemocytes of *D. cingulatus* are similar with those reported by Arnold (1952a) on *Ephestia kuhniella.* The effect of insecticides or poisons on the haemocytes of insects have also been studied by a number of workers. Arnold (1952b) observed a significant decrease in the THC in *Ephestia kuhniella* when treated with dichloroethyl bromide. On the contrary, Jones and Tauber (1954) observed a significant increase in THC in last instar *Tenebrio* larvae following fumigation with nicotine, whereas, a decrease in the THC as a result of insecticidal poisoning was found in *Locusta migratoria* (Pilat, 1935) and *Blattella orientalis* (Fisher, 1936). But increase in THC was noted in *Chrysomela decemlineata* (Arvy *et al.*, 1950) and *Periplaneta americana* (Gupta and Sutherland, 1968). Basu and Raychaudhury (1975) also reported increase in THC when *P. americana* were treated with malathion and benzene hexachloride. In *Poecilocerus pictus* treated with dichlorvos and phosphamidon, a reduction in THC was recorded for first two days (Shukla and Bahadur, 1986). Zaidi and Khan (1977) observed that all types of haemocytes of the adult males and the females of *D. cingulatus* were pathologically affected by the topical application of the technical aldrin and dipterex. The maximum pathological conditions of the haemocytes were observed after 72 hours following topical application of 2% aldrin when the destruction of adipohaemocytes occurred, whereas, topical application of 1.5% dipterex showed complete destruction of adipohaemocytes and they concluded that the most sensitive haemocytes to these insecticides were the adipohaemocytes and granular haemocytes. Similarly, Ahmad and Khan (1987) observed that the topical application of sublethal concentrations of either DDT or furadan on the 4th instar larvae of *Spilosoma obliqua* resulted in the pathological conditions in all types of haemocytes, and adipohaemocytes, podocytes as well as plasmatocytes were relatively more damaged by both the insecticides. Keeping in view of the role of haemocytes in reproduction and the effect of insecticides on haemocytes, it can be concluded that in the present investigation the topical application of the aforesaid insecticides (organophosphate and carbamate) on *Dysdercus cingulatus* and *Diacrisia obliqua* may result in the destruction of the haemocytes which ultimately leads to the inhibition of fecundity and fertility of the adult females. As reported earlier (Bahadur and Pathak, 1971; Arnold, 1974) that there exists difference in

haemocyte counts in the two sexes of an insect species, similarly, Zaidi and Khan (1975) also recorded a significantly higher number of haemocytes (THC) in the females than in the males of the same age and stage. This difference has been attributed to the differences in JH titre between the two sexes (Arnold, 1974). Similarly, the changes in the haemocyte numbers at different time in the life cycle of insects, obviously are the result of fluctuation of hormonal titre (Wiggleswort, 1959; Arnold, 1974). In *Locusta* the endocrine glands have been shown to regulate haemocyte counts and blood volume (Hoffman, 1970). Similarly, humoral control over haemocyte activity has been demonstrated in *Drosophila* (Rizki, 1957). Crossley (1964) observed that there is a premature shift in the haemocyte population in *Calliphora* larvae when injected with ß-ecdysone. An extensive involvement of endocrines in differentiation of haemocytes and their count has also been reported by Crossley (1976). Similarly, Maheshwari and Sehgal (1979) observed an alteration in hemogram of *Dysdercus koenigii* by the topical application of tepa and thiotepa. In the light of the above said facts, it can be summarized that the insecticides might have a direct effect on the endocrine system which in turn influence upon the circulating haemocytes population of an insect. The suggestion that the gonads form the direct target organ of the insecticides may not be taken as a simple one. The alteration in the haemocyte count has definite bearing on the hormonal imbalance which indeed is by the insecticides. This imbalance in the hormonal titre undoubtedly tells upon its effects on the development of the gonads and inhibits the reproduction.

Lange and Kreuger discovered the biological activity of organophosphorous esters for the first time in 1932 (Mulmule *et al.*, 1988). Since then, a large number of such compounds have been developed. The carbamate insecticides are known to be similar, in many ways to organophosphate insecticides. Both groups of cornpounds are cholinesterase (ChE) inhibitors. A number of workers have studied the insecticidal effects of these compounds on the life cycle, fecundity and fertility of insects. But the gross pathology generally has received little attention such that the knowledge regarding this is very scanty (Mulmule *et al.*, 1988). Most of the studies regarding the histopathological effects of pesticides on insects were concerned with chemosterilants, hormones, antijuvenile hormones or plant products. Besides the

conventionally used insecticides, there are a number of chemosterilants which also belong to organophosphorous group. These organophosphorous chemosterilants are either alkylating (e.g. tepa, thiotepa, apholate etc.) or non-alkylating types (hempa, thiohempa etc.). The gross pathologies of reproductive organs have been repeatedly observed after the treatment of insects with chemosterilants (Hathaway *et al.*, 1966; Young and Snow, 1967; Mendoza and Peters, 1968; Sprenkel and Yendol, 1969; Kaloostian, 1970; Sukumar and Naidu, 1973; Jalaja and Prabhu, 1976; Ansari and Khan, 1977, 79; Lau and Sudderuddin, 1979; Bhatnagar, 1980; Ahmad, 1980). Furthermore, pathology of the reproductive organs has also been studied by exposing the insects to X-rays (Theunissen, 1977; Srivastava and Despande, 1983; Srivastava *et al.*, 1985), to antijuvenile hormones (Deb and Chakravorty, 1982; Masner *el at.*, 1979), to plant products (Saxena and Srivastava, 1972; Prabhu and John, 1975; Koul, 1979; Rembold and Sieber, 1981; Schmidt and Brocher, 1981; Schulz, 1981; Katiyar and Srivastava, 1982; Schulz and Schluter, 1984; Dorn *el al.*, 1986; Saxena, 1987; Koul *et al.*, 1987), or to hormones (Masner, 1967; Masner, 1969; Rohdendorf and Sehnal, 1973; Jalaja *et al.*, 1973; Karnavar, 1973; Landa and Metwally, 1974; Rohdendorf, 1975; Judson *et al.*, 1978; Chakravorty, 1981; Gelbic and Metwally, 1981; Maruthi *et al.*, 1982; Revathy *et al.*, 1982; Roychoudhury and Chakravorty, 1986, '87; Mukhopadhyay *et al.*, 1988, '89; Deb and Jacob, 1989).

The histopathological studies with respect to the insecticides were mostly concerned with fishes (Kumar and Panth, 1984b, '85, '88; Ram and Sathyanesan, 1983; Saxena and Garg, 1978) or with aquatic insects or mammals (Wyrobek *et al.*, 1981; Salmon *et al.*, 1985; Dodd and Fowler, 1986; Panth *et al.*, 1987; Arora and Vijayaraghavan, 1989; Singh and Pandey, 1989). However, the histopathological investigations to determine the effects of insecticides on terrestrial insects have received comparatively little attention. This information is also available from Ahi (1988). So far, studies relating to the histopathological effects induced by acephate, ethion and dichlorvos (organophosphate) and furadan, carbaryl and aminocarb (carbamate) insecticides on the reproductive organs of *Dysdercus cingulatus* and *Diacrisia obliqua* have not been made . Therefore in the present investigation, the anatomical and histological deformities following the topical application of the above

said selected insecticides were observed. Since such studies have not been described in insects so far, the present observations can be compared with the available records of tissue stress induced by the chemosterilants or hormones on the reproductive organs of other insects. In the present study on *D. cingulatus* and *D. obliqua*, the spermatogonia in the testes of the males, emerged from the treated nymphs or the larvae with the selected organophosphate or carbamate insecticides, were not affected. Furthermore, it was also evident that both groups of insecticides (organophosphate and carbamate) could not cause reduction in the density of different spermatogonic structures (spermatogonia, spermatocytes, spermatids and matured spermatozoa) of testicular follicles. However, when these treated males were mated with treated females, the hatchability of the eggs was low. Such unhatched eggs did not show any embryonic development, indicating the embryonic death in the eggs. But it was not confirmed cytologically whether preliminary cleavage divisions in the fertilized eggs occurred or not. The colour of the eggs having pre-embryonic death was unchanged, whereas, the eggs undergoing post-embryonic development changed their colour from creamish white to bright orange as also observed by Ansari (1976). Similarly, the colour of the eggs of *D. obliqua* having pre-embryonic death was unchanged, whereas, the eggs entering in their post-embryonic development changed the colour from yellowish green to black. Therefore, the above mentioned observations collectively led to the belief that some sperms of treated males may contain dominant lethal mutations which are responsible for the pre-embryonic death in the eggs.

In insects, Muller (1927) for the first time used and clearly defined the term "dominant lethal mutation" in the same classic paper in which he reported the discovery of the mutagenic effects of radiations. Sonnenblick and Henshaw (1941) properly defined the term dominant lethal mutation as "Dominant lethals are nuclear alterations which can affect the death of the zygote even though they are present in single doses, that is introduced by but one of the germ cells which unite at fertilization". The induction of dominant lethal mutations in insect reproductive cells usually does not hinder the maturation of the treated cell into a gamete or the participation of the gametes in the formation of a zygote but prevents the zygote from developing to maturity. A lethal mutation can be expressed at any stage in the

insect's life cycle, but death usually occurs before hatching (Wright and Pal, 1967; Ansari, 1976). Thus, the lethal mutation is not really fatal to the treated cells but it is so to its descendant i.e. the zygote. The polyfunctional mutagenic aziridines including TEM (Triethylenemelamine) were reported to induce dominant lethal mutations in the sperms of insects by many workers. Apholate (a highly mutagenic polyfunctional chemosterilant) did not cause any histological damage in the testes, but motile sperms having dominant lethal mutations were produced in *Musca domestica* (LaBrecque, 1961), *Aedes aegypti* (Rai, 1964), *O. melanopus* (Ezueh and Hoopingarner, 1967) and *D.U. howardi* (Hamilton and Sutter, 1969). Similarly metepa in *C. chinensis* (Nakayama and Nagasawa, 1966), tepa in *D. cingulatus* (Outram and Campion,1967), TEM in *Drosophila melanogaster* (Fahmy and Fahmy, 1954, 1964, 1969), *B. hebetor* (LaChance and Leverich, 1968) and *O. fasciatus* (Economopoulos and Gordon, 1969) produced dominant lethal mutations in the sperms without affecting histological structure of the testes. Studies with some chemical pesticides (other than alkylating agents) have shown that these pesticides may also produce aberrations in chromosomes (Majumdar *et al.*, 1976; Kopelman and Schnitman, 1976). These workers reported the aberrations produced by dieldrin in the bone marrow cells of STS mouse and WI-38 human cell lines. In another cell study of lymphocyte culture of semi-domestic Mallard ducks, significant numbers of chromosome aberrations were observed at a dosage level of 100 ppm of dieldrin (Bunch and Low, 1973). Ara and Adhami (1983) studied the effect of DDT and Dieldrin on the somatic chromosomes of *Culex pipiens fatigans* and observed that at higher concentrations of these insecticides (5 ppm and 4 ppm, respectively) the chromosomes become very sticky, losing their separate entity. This extreme stickiness due to many breaks resulted in clumping of the chromatids. The mutagenic effects of organophosphorus insecticides have been studied by Fishbein (1976), who concluded that nuclei are affected by these compounds. In adult house fly males, application of TEM (triethylenemelamine) destroyed all the spermatogonia besides the induction of dominant lethal mutations in spermatids and spermatozoa (Kissan *et al.*, 1967). Ahi (1988) observed that the injection of hexachlorocyclo hexane (HCH) an organochlorine insecticide to the adult males of *Poecilocerus pictus* resulted in loosening of the germ cells, pycnosis of the spermatogonia, spermatocytes, hypertrophied spermatids, hypertrophied and dissociated

spermatozoa, the formation of brown coloured body between the testes follicles and their subsequent melanization, and concluded that HCH makes the tissue hyperactive and probably there is a stress factor which brings about cellular deformations. But in the present investigations on *Dysdercus cingulatus* and *Diacrisia obliqua,* the spermatogonia in the testes of the males emerged from the nymphs or larvae treated either by any of the selected organophosphate or carbamate insecticides were not affected.

In the females of *Dysdercus cingulatus* and *Diacrisia obliqua* affected either by organophosphate or carbamate insecticides, the reduction in the fecundity might be due to the destruction and resorption of germarium and ovarian follicles of the vitellarium depending on the concentration of these insecticides. The ovaries of the affected females of *D. cingulatus* emerged from both 4th and 5th instar treated nymphs became smaller in size because of the inhibition of growth and disintegration as well as resorption of the internal cellular contents of the ovarioles. Similarly, the ovaries of *D. obliqua* females emerged from the treated larvae of both 5th and 6th instars shorten in size due to the inhibition of ovarian growth. However, the sexual behavior of such affected males and females did not show any change. In *D. cingulatus* females the most sensitive region indicating the beginning of the effect of insecticide was the proximal zone of the germarium. This zone bears the prefollicular tissue where active cell division occurs to increase the population of prefollicular cells and also continuous differentiation of young oocytes takes place. The second sensitive area was the middle zone of the germarium which contains both the mononucleate trophocytes (MNT) and binucleate trophocytes (BNT) as well as the trophic core. The third region which shows the degenerative effect of the above said selected insecticides is the vitellarium along with oocytes and the interfollicular plugs.

The most susceptible region to these insecticides (organonphosphate and carbamate) is the area where active proliferation of the prefollicular cells takes place. These cells first undergo the clumping in their nuclear chromatin and later suffer necrosis and finally their debris is resorbed. Mulmule *et al.* (1988) studied the contact effect of two organophosphorus insecticides (SAN-322 and DDVP) on the

ovaries of Meloid beetle *Mylabris pustulata* and recorded vacuolation, degeneration and resorption of the oocytes and yolk material in the ovaries of the affected beetles. Furthermore, the degeneration and necrosis of the follicular epithelium are also observed indicating the probable cytotoxic effects of SAN-322 and DDVP. Similarly the injection of 12.5 μg metepa or 7.5 μg apholate to newly moulted adult females of *D. cingulatus* resulted in disintegration of the germarium and follicular epithelium as well as the reduction in the size of oocytes and finally their resorption (Jalaja and Prabhu, 1976).

In normal ovarioles the young oocytes enter the transition region between the germarium and the vitellarium. The most rapidly growing oocytes occupy the central position in this region and thus a linear arrangement of younger oocytes is formed, which in turn is surrounded by prefollicular tissue. Later the prefollicular cells around a growing oocyte differentiate into a regular layer of follicular epithelium and finally a separate egg chamber is formed. In this way many egg chambers are arranged in a linear fashion in the upper part of the vitellarium (previtellarial region). The paucity of the prefollicular cells is rapidly augmented by an intensive mitotic division in this region. Similar process of follicle formation has been described in the telotrophic ovaries of *O. fasciatus* (Bonhag and Wick, 1953), *P. apterus* (Merle, 1969) and *D. fasciatus* (Brunt, 1971).

In treated *Diacrisia obliqua*, the cellular structure of the germinal portion of the affected ovaries was unchanged. However, the number of primordial germ cells was less when the treatment was done with furadan. The size of the ovaries was reduced remarkably and in some ovarioles loop formation was also recorded. The density of the ooplasm was low and the cytoplasm of some trophocytes was less granulated than normal trophocytes. The accumulation of a few chorionated eggs at the junction of the ovariole and the lateral oviduct resulted in the formation of a bulbus structure. In some ovarioles, the linear arrangement of both the mature and immature eggs was disturbed and a gap between the egg surface and ovariole wall was formed. Deb and Chakravorty (1982) also recorded similar anomalies in the ovaries of *Corcyra cephalonica* following the application of 100 μg precocene-II on the last larval instar. Similarly, the topical application of 100 μg and 10 μg

hydroprene (Altozar or ZR-0512) per last instar larvae and pupae of *Corcyra cephalonica* (Lepidoptera) resulted in the reduction of the germarium and immature part of the vitellarium. The number of eggs in an ovariole was significantly less and loop formation was the important abnormality. In some oocytes which are situated at the middle part of the ovarioles, the ooplasm was divided into a central rounded mass and a main peripheral mass with a wide space. In some malformed oocytes, the follicle cells underwent shrinkage. The bursa copulatrix was small and less sclerotized (Deb and Chakravorty, 1981). In the present investigation, similar results were recorded following the topical application of higher sublethal concentrations of the above said selected organophosphate and carbamate insecticides.

In the affected females *of D. cingulatus* the prefollicular cells undergo masive destruction which result in several anomalies in the ovarioles. First and major effect is the formation of compound egg chamber in the previtellarium. Before an oocyte is completely enveloped by prefollicular cells it descends to the neck of the vitellarium and then another naked oocyte also reaches there followed by one or more. Thus more than one oocytes are enveloped in a single chamber resulting in the formation of a compound egg chamber. In such chambers the growth of the oldest oocyte is most pronounced, and it seems likely that this oocytes still has its nutritive connection with the trophic core. The formation of such compound egg chamber in the telotrophic ovaries has also been reported in *P. apterus* by 6-azauridine (Masner and Landa, 1971); in *Rhodnius prolixus* by aminopterin (Patchin and Davey, 1968) and in *D. cingulatus* by apholate and metapa (Jalaja and Prabhu, 1976).

In certain other cases, the descent of some younger oocytes to the vitellarium is inhibited due to the acute shortage of prefollicular cells, consequently, these oocytes are retained in the germarium and start their development. The rate of their growth and maturation is often higher than those in the vitellarium as these oocytes of the germarium remain in direct contact with the trophic core and trophocytes till they degenerate. In such cases the formation of compound egg chambers also ceases. However, in *P. apterus* (Masner and Landa, 1971) compound oocytes were reported in the compound egg chambers and oocytes were not retained in the germarium.

The third anomaly due to the lack of prefolliculer tissue is the absence of linear arrangement of oocytes in the ascending order of the size within the vitellarium. Therefore, the germarium, is directly followed by a large oocyte. This was also reported by Masner and Landa (1971) in *P. apterus*. The fourth abnormality was the inhibition of the increase in length of the previtellarium and vitellarium because of the absence of the source of the precursors of follicular epithelium. Consequently the ovaries of the affected *D. cingulatus* females become much smaller than those of the control of the corresponding age. The topical application of 2.5% penfluron on freshly moulted females of *D. cingulatus* resulted in abnormal changes in the ovaries 24 hours post-treatment. The disorganization of oocytes started within 48 hours and the ovarioles appeared smaller than control ovarioles (Satyanarayana *et al.,* 1985). Similarly it had been found that tepa, a chemosterilant, could degenerate the ovary of *Dysdercus* into a digitate lump of aborted ovarian mass (Sukumar and Naidu, 1973).

The next vulnerable area is the apex of the germarium where active mitotic activity occurs to form new trophocytes. Under normal conditions the trophocytes occupying the upper part of the germarium, show a distinct polarization. There is a developmental gradient starting from the apex, where the smaller cells still mitotically divide and move posteriorly where the older trophocytes undergo a transformation, characterized by endomitotic replication of the DNA and tremendous growth of the whole nucleus. The giant trophocytes release RNA rich material towards the central trophic core, and finally completely disintegrated. This loss of trophocytes is continuously substituted by mitotic activity of the apical cells. In *Dydercus cingulatus* the topical application of furadan causes more damage to the trophocytes in the germarium. The older trophocytes which are under endomitotic phase, are easily destroyed. This endomitotic phase of trophocytes is even more susceptible than the cells of the apex of germarium forming new trophocytes. In *Cochliomyia hominivorax*, the nurse cells under endomitotic phase were most susceptible when the treatment was made with tretamine (Crystal and LaChance,1963). Similar results were also obtained in the same species by other alkylating agents (LaChance and Leverich, 1968). Thus owing to the decimation of the trophocytes,

the release of RNA-rich material towards the central trophic cores is also inhibited. The destruction of the trophocytes signals the final cessation of maturation and growth of oocytes in the ovarioles. As this nutrient supply of the developing oocytes in the vitellarium is cut due to the degeneration of trophic core, these oocytes of the vitellarium also start vacuolization and finally collapse and disintegrate. Inhibition of oocytes maturation due to destruction of nurse cells causing complete infecundity in females treated by chemicals was reported in *Musca domestica* (Morgan and LaBrecque,1962 and 1964; Landa and Rezabova, 1965; Morgan, 1967), *C. hominivorax* (Crystal and LaChance, 1963, LaChance and Leverich, 1968), *Drosophila melanogaster* (Cantwell and Henneberry, 1963), *Aedes aegypti* (Rai,1964), *Culex pipiens fatigans* (Grover, *et al.*, 1972), *Bombyx mori* (Sugai and Uchino, 1969), *Oncopeltus fasciatus* (Economopoulos, 1971) and *Dysdercus cingulatus* (Sukumar and Naidu, 1973).

Proteins are considered as the primary components of the living matter and provide most of the building material. The process of growth and reproduction are regulated by the formation and degradation of proteins as well as nucleic acids in the presence of enzymes. In a variety of insects, the proteins of the haemolymph have been estimated in relation to their reproductive activity. The information on the protein concentrations of the haemolymph of various insects was reviewed from time to time (Buck, 1953; Wyatt, 1961; Florkin and Jeuniaux, 1964; Chen, 1966).

The blood protein concentration in females generally increase during the earlier part of vitellogenesis (Highnam,1962; 1964; Hill, 1962; Slama, 1964; Mills *et al.*, 1966; Engelmann, 1968; Prabhu and Nayar, 1971), and the growing oocytes take up at least some of the blood proteins unaltered through the follicle epithelium into the oocytes by pinocytosis (Anderson, 1964; Roth and Porter, 1964). The mechanism involved in the control of build-up of the blood proteins and their entry into oocytes is different in different insects (Highnam,1964; Engelmann and Panney, 1966; Engelmann, 1968). In most insects the median neurosecretory cells of the brain stimulate synthesis of the protein and their subsequent release into blood, whereas, the carpus allatum facilitates their entry into the oocytes (Hill, 1962; Highnam,1964; Highnam *et al.*, 1963; Highnam *et al.*, 1963). The follicle epithelium

in insect ovaries is known to synthesize and secrete proteins (Anderson, 1971). The corpus allatum hormone influences follicle epithelium which controls the uptake of blood proteins by the oocytes (Highnam *et al.*, 1963). Similarly, Jalaja and Prabhu (1971) observed that the blood proteins concentration of *Dysdercus cingulatus* on day 1 was about 7.2 gm/100 ml, whereas, on day 2, it reached up to 12.2 gm/100 ml and on day 3 it was almost 17 gm/100 ml. But on day 4, the protein concentration in the blood fell to the level of day 1 which clearly indicates that all the excess proteins were apparently utilized by the growing oocytes and they concluded that protein build-up in the blood on one hand, and its deposition as yolk in the oocytes on the other, were controlled by 2 factors in *D. cingulatus*: the former probably by neurosecretion from the brain and the latter by the corpus allatum hormone. The observations of Prabhu and Nayar (1971) on blood protein concentration of female *D. cingulatus* are also in line with those on most other insects in which there was a sharp initial rise in the blood protein concentration and subsequent fall coinciding with the early period of vitellogenesis (Highnam, 1962; Hill, 1962; Slama,1964; Mills *et al.*, 1966). On the basis of these results Prabhu and Nayar (1971) suggests that in *Dysdercus* the synthesis of blood proteins and their release into the blood stream are controlled by neurosecretions, while their entry into oocytes is controlled by the carpus allatum hormone as in *Schistocedrca* (Hill, 1962, Highnam *et al.*, 1963; Highnam, 1964). Similarly, the role of neurosecretory cells of brain in the synthesis of proteins and their subsequent release into blood has also been confirmed by Jalaja *et al.* (1973) when they extirpated the cerebral neurosecretory cells of the pars intercerebralis of the red cotton bug, *Dysdercus cingulatus* and found shorter ovaries, smaller oocytes, reduced number of oocytes undergoing vitellogenesis and smaller follicle cells with smaller nuclei. It is apparent from the above findings that the total protein level in blood influences the maturation of ovaries, oocytes and vitellogenesis. Furthermore, the application of insecticides, like aldrin and diptrex on *D. cingulatus* (Zaidi and Khan, 1981) and endosulfan and malathion on *Spodoptera litura* (Prasad and Nath, 1986), resulted in the decline in the total protein level of the haemolymph. Thus any adverse effect on the protein level may also affect the ovarian growth and oocytes maturation. Some insecticides and chemosterilants are found to interfere with DNA and protein molecules. According to Alexander (1960) the alkylating agents affect the synthesis of proteins, nucleic acids and different

vitamins. Furthermore, Fahmy and Fahmy (1964) also explained the action of alkylating agents on DNA and proteins leading to chromosome breakage. Inhibition of DNA synthesis by apholate in the nurse and follicular cells of the ovary is well known in stable flies (Chamberlain and Barrett, 1968), by apholate and hempa in *A. aegypti* (Madhukar *et al.*, 1970) and in *C. p. fatigans* (Grover *et al.*, 1971).

In the present investigations on *Dysdercus cingulatus* and *Diacrisia obliqua*, the treatment of insecticides caused infecundity, infertility, abnormal oocytes, underdeveloped ovaries and various degrees of cellular disintegration depending on the concentrations of the insecticides involved as well as the age and stage of insects. On the basis of these findings, it can be inferred that here as well an intermediate step may be involved in which the insecticide may affect the haemolymph proteins, cell division, DNA synthesis, which ultimately has a bearing upon the abnormalities found in the ovaries of the treated insects.

The females of *D. cingulatus* emerged from the treated nymphs with the lower concentrations of either organophosphate or carbamate insecticides, initially develop insignificant infecundity but later there was recovery in them. When such females were dissected, the ovarioles of each ovary had almost completely matured eggs wrapped in a normal chorion and occasionally a few matured eggs were retained in the lateral as well as common oviduct. These eggs were generally smaller than normal and sometimes irregular in shape. The percentage of hatching in these eggs was very poor. The majority of these eggs died at post embryonic stage. Inhibition of post embryonic development in these eggs can be explained on the basis of deficiency of the necessary nutrients because the trophocytes were destroyed and yolk deposition was suffered. This is supported by the histological picture of the maturing oocytes of the treated females of *Dysdercus cingulatus*. On the contrary in *A. aegypti* the cause of low hatching in the eggs of apholate treated females was assigned to the induction of dominant lethal mutation (Rai,1964). However, low hatching was also recorded in the eggs of *B. hebetor* females treated with some degradation products of carbamate pesticides which are non-mutagenic agents (Grosch and Hoffmans, 1973). Therefore, the reason for inhibition in the development of eggs can not be explained on account of dominant lethal mutation in

such eggs. This view further gets strength from the observations on *O. fasciatus* (Economopoulos, 1971) in which TEM-treated females laid eggs deficient in nutrients. Similar explanation was given for the low hatching rate in the eggs of *Musca domestica* females treated with furyltriazine (Matolin and Landa, 1971).

The application of insecticides on insects was emphasized on the basis of age and stage to obtaine complete or partial infecundity and infertility. The differentiation of oocytes and trophocytes in the germarium of *D. cingulatus begins* at the nymphal stage. It is also well established that, of the two life stages, generally the nymphal or larval stages were more susceptible than the adult stages. Thus, the application of insecticides especially organophosphate and carbamate can be successfully used at the nymphal or larval stages to get complete or partial infecundity.

The present investigation on *Dysdercus cingulatus* and *Diacrisia obliqua* revealed that the application of conventionally used insecticides (organophosphate and carbamate) on the nymphal and larval stages developed infecundity and infertility in the affected females due to direct pathological and physiological causes. Sterility of males as well as infecundity and infertility of females both may be effective control measures on these species.

VI-SUMMARY

The wisdom of widespread use of insecticides has been questioned with the advent of more ecologically sound IPM (Integrated Pest Management) to pest control. So, the use of small quantities of easily degradable pesticides might be safer for the ecosystem which on one hand kills the insect up to tolerable level and on the other hand restrict the numerical strength of the surviving insect. With this view in the present investigation the sublethal concentrations (based on Lc-50 value) of recently used organophosphate and carbamate insecticides, having less mammalian toxicity and most widely in use, have been tested on the red cotton bug *Dysdercus cingulatus* and Bihar hairy caterpillar *Diacrisia (Spilosoma) obliqua* and the salient features of the results are summarized below:

1. Comparative effects of three modern organophosphates (Acephate, Ethion and Dichlorvos) as well as three carbamate compounds (Furadan, Carbaryl and Aminocarb) were investigated with regard to mortality, moulting, longevity, fecundity and fertility of *Dysdercus cingulatus* (a cosmopolitan pest of cotton and other malvaceous plants) and *Diacrisia (Spilosoma) obliqua* which is a serious pest of vegetables and several cash crops.

2. Only five sublethal concentrations of each of the above mentioned insecticides, based on Lc-50 value with respect to the insect concerned were tested

3. For *D. cingulatus,* among the three organophosphate (OP) insecticides, the five selected sublethal concentrations were:

0.002, 0.001, 0.0008, 0.0006, and 0.0004% for Acephate

0.006, 0.004, 0.002, 0.001, and 0.0008% for Ethion

0.01, 0.008, 0.006, 0.004, and 0.002% for Dichlorvos

Similarly, among the three carbamate (CM) insecticides, the five sublethal concentrations were:

0.001, 0.0008, 0.0006, 0.0004, and 0.0002% for Furadan

0.0025, 0.0020, 0.0015, 0.0010, and 0.0005% for Carbaryl

0.004, 0.002, 0.001, 0.0008, and 0.0006% for Aminocarb

4. For *Diacrisia obliqua*, the five different sublethal concentrations were:

0.1, 0.08, 0.06, 0.04, and 0.02% for Acephate

0.6, 0.4, 0.2, 0.1, and 0.08% for Ethion

0.4, 0.2, 0.1, 0.08, and 0.06% for Dichlorvos.

Similarly, among the three carbamate compounds, the five sublethal concentrations were:

0.08, 0.06, 0.04, 0.02, and 0.01% for Furadan

0.15, 0.10, 0.08, 0.06, and 0.04% for Carbaryl

0.25, 0.20, 0.15, 0.10, and 0.08% for Aminocarb.

5. Each sublethal concentration of the selected compounds was topically applied through a tuberculin syringe fitted with a manually operated microapplicator in a uniform volume (1 μl) on individual 4th and 5th instar nymphs (one day old) of *D.cingulatus* and 2μl on 5th and 6th instar larvae of *D. obliqua,* so as to assess the comparative and far reaching effects (residual effect) pertaining to younger and older nymphal or larval stages.

6. Out of the three tested organophosphates, acephate was most toxic insecticide to both 4th and 5th instar nymphs of *D. cingulatus,* followed by dichlorvos and ethion. The effects were concentration based.

7. Similarly, out of the three tested carbamates, furadan was most effective with regard to toxicity to both 4th and 5th instar nymphs of *D. cingulatus*, followed by carbaryl and aminocarb. The effects were concentration based.

8. Further, the topical application of sublethal concentrations of acephate on 4th and 5th instar nymphs of *D. cingulatus* caused more significant reduction in the average egg production and egg hatching of the females compared to those which emerged from 4th and 5th instar nymphs treated with ethion and dichlorvos.

9. Likewise, among the present carbamate compounds, the topical application of furadan was most effective in inducing infecundity and infertility in the eggs of the females, followed by carbaryl and aminocarb.

10. In comparison to advanced stage (i.e. 5th instar), in case of *D. cingulatus*, the penultimate instar (i.e. 4th instar) was more susceptible to all the selected organophosphate as well as carbamate insecticides when applied topically.

11. Simultaneously following the application of the present organophosphate (acephate, ethion and dichlorvos) and carbamates (furadan, carbaryl and aminocarb) on the nymphal stages of *D. cingulatus,* observations were also made on the gonads of adults that emerged from the treated nymphs.

12. The application of above said concentrations of organophosphate and carbamate insecticides did not cause any anatomical or histological damage to the testes of the adult males which emerged from the 4th and 5th instar treated nymphs of *D. cingulatus.*

13. Further, motile sperms produced by the male emerged from treated nymphs with either group of insecticides (organophosphate and carbamate) were successfully transferred to the spermathecae of the females during copulation. Therefore, the sterility of the males caused by these insecticides was owing to induction of dominant lethal mutation in the spermatozoa.

14. However, topical application of all concentrations of acephate, ethion and dichlorvos (organophosphate) on 4th and 5th instar nymphs of *D. cingulatus* caused a number of pathological changes in the ovaries of the females which emerged from them.

15. The topical application of higher concentrations (0.002 and 0.001) of acephate on *D. cingulatus* nymphs caused reduction in the number of oocytes/ovariole as well as reduction in the size of ovary, degeneration and resorption of a few oocytes, clumping of proteins in trophocytes of germinal portion, absconding of trophic core and nutritive cord in some emerged females. The recovery in such ovarioles was never recorded.

16. Likewise, the application of present concentrations of furadan, carbaryl and aminocarb (carbamate) on the 4th and 5th instar nymphs of *D. cingulatus* also resulted in some pathological damages in the ovaries of ensuing females.

17. The application of higher (0.001, 0.0008, and 0.0006%) sublethal concentrations of furadan on the nymphal stages significantly inhibited the size of the ovaries, reduced the number of oocytes almost to half, resulted in clumping of chromatin in the posterior region in germarium and caused thinning of the nutritive cord up to such extent that it lost its connection with trophic core in the emerged females. Further, the recovery in such ovaries was never recorded. However, such damage was less marked by the application of carbaryl and aminocarb.

18. Several damages were also accompanied with inhibition of mitosis in the apical region and clumping of chromatin in the endomitotic trophocytes which resulted in depletion of nutritive tissue leading to disturbances in previtellogenesis and activation of some oocytes in the vitellarium. Consequently, the oocytes developed many vacuoles and later they collapsed and degenerated.

19. Most of the oocytes present in the ovaries reached to maturity and transformed into eggs with a complete chorion around them, however,some of the eggs were smaller in size due to inadequate supply of the nutritive material which were occasionally retained in the ovarioles. Their orientation in the ovarioles was often anomalous.

20. Many of the smaller eggs of the treated females, after oviposition, became dead during embryonic development.

21. The most sensitive region of the ovarioles for acephate, ethion, furadan and carbaryl was prefollicular area where active mitosis takes place. The trophocytes having endomitotic stages were the most sensitive tissue, whereas, the third susceptible region was the anterior part of the germarium where active mitosis occurs.

22. Out of the three selected organophosphate insecticides, ethion was the most toxic compound to both 5th and 6th instar larvae of *Diacrisia obliqua,* unlike in the case of *D. cingulatus*, followed by dichlorvos and acephate. The effects were concentration based.

23. Likewise, out of the three tested carbamate insecticides, similar to the case of *D. cingulatus,* furadan proved most toxic insecticide to both 5th and 6th instar larvae of *D. obliqua* followed by carbaryl and aminocarb. The effects were concentration based.

24. Following the topical application of three organophosphates on 5th and 6th instar larvae of *D. obliqua*, dichlorvos showed best inhibitory effect on fecundity and fertility of the females. Whereas the topical application of ethion and acephate on 5th and 6th instar larvae were comparatively weaker in effect.

25. Following the topical application of sublethal concentrations of three carbamate insecticides on the 5th and 6th instar larvae of *D. obliqua*, furadan caused best inhibitory effect on fecundity and fertility of the emerged females followed by carbaryl and aminocarb like in case of *D. cingulatus.*

26. In comparison to advanced larval stage (i.e. 6th instar larvae), the penultimate instar (i.e. 5th instar) was more susceptible to all the sublethal concentrations of the present organophosphate and carbamate insecticides like that of *D. cingulatus.*

27. Simultaneously, the effect of topical application of present sublethal concentrations of organophosphate (acephate, ethion and dichlorvos) and carbamate (furadan, carbaryl and aminocarb) on the larval stages (5th and 6th) was subsequently studied on the gonads of adult *D. obliqua* which emerged from treated larvae.

28. The application of all the selected insecticides of either organophosphate or carbamate group on the larval stages did not cause any anatomical or histological damage in the testes of the adult males which emerged from the treated 5th and 6th instar larvae of *D. obliqua.*

29. Further, motile sperms produced by males emerged from treated larvae with either groups of insecticides were successfully transferred to the spermathecae of the females during copulation. Therefore, the sterility of the males caused by these insecticides might be due to the induction of dominant lethal mutation in the spermatozoa.

30. The topical application of sublethal concentrations of acephate, ethion and dichlorvos on 5th and 6th instar larvae of *D. obliqua* resulted in a number of pathological changes in the ovaries of the emerged females. Although, the nature of damage was almost identical, the degree of damage was concentration based.

31. Following the topical application of the higher sublethal concentrations of acephate(0.1 and 0.08%), ethion (0.6 and 0.4%) and dichlorvos (0.4 and 0.2%) on 5th and 6th instar larvae of *D. obliqua* in the emerged females, the size of the ovaries reduced significantly. There was a loose arrangement of the chorionated eggs at the base of the vitellarium. Some ovarioles formed a loop. The bursa copulatrix was smaller in size and became less sclerotized. The immature and mature eggs were not linear arrangement.

32. Likewise, the application of sublethal concentrations of furadan, carbaryl and aminocarb (carbamate) on 5th and 6th instar larvae of *D. obliqua* also caused significant pathological damages in the ovaries of the emerged (affected) females.

33. The application of higher sublethal concentrations of furadan (0.08%, 0.06% and 0.04%) caused more severe damages to the ovaries of the emerged (affected) females as compared to carbaryl and aminocarb.

34. The size of the ovaries of the females, which emerged from the 5th and 6th instar larvae after the application of higher sublethal concentrations of furadan (0.08, 0.06 and 0.04%), carbaryl(0.15 and 0.1%) and aminocarb (0.25 and 0.20), reduced

remarkably. In some cases the distinction between the germarium and vitellarium was obscured. In the germarium of some ovarioles the number of primordial germs cells reduced significantly. In few ovarioles, the number of eggs in the vitellarial part was less than normal. The follicle cells were loosely arranged leaving some small space between them. The central mass of ooplasm of some oocytes completely separated from the peripheral mass by a small gap. The accumulation of yolk protein spheres were not normal and the ooplasm of chorionated eggs showed differential growth pattern.

Abbreviations for plates

AcGl	Accessory gland
Aed	Aedeagus
b	Binucleate trophocytes
bc	Bursal sac
bcpx	Bursa copulatrix
Be	Bulbus ejaculatorius
Bej	Bulbous ejaculatorius (*Diacrisia obliqua*)
bf	Binucleate follicular cells
c	Chorion
cc	Clumped mass of chromatin
CdAcGl	Common duct of accessory gland
cl	Carpus luteum
Co	Common oviduct (*Dysdercus cingulatus*)
d	Disintegrated cells
Dej	Ejaculatory duct
dGl	Common duct of accessory gland
dvsm	Seminal vesicle duct
Ej	Ejaculatory duct
f	Follicular epithelium
Gr	Germarium (*Dysdercus cingulatus*)
Grm	Germarium (*Diacrisia obliqua*)
gv	Germinal vesicle
in	Inner sheath
ip	Interfollicular plug
is	Intercellular space
Lo	Lateral oviduct (*Dysdercus cingulatus*)
m	Multilayered follicular epithelium
Md	Mesadene
n	Nucleus
nc	Nutritive cord
o	Oocytes
Odc	Common oviduct (*Diacrisia obliqua*)
Odl	Lateral oviduct (*Diacrisia obliqua*)
os	Outer sheath
Ovl	Ovariole
p	Pedicel
pc	Prefollicular cells
Rect	Rectum
ResAcGl	Reservoir of accessory gland
SpGl	Spermathecal gland
Spr	Spermathecal reservoir
Spt	Spermatheca
Sv	Seminal vesicle
t	Trophocytes
tc	Trophic core

Te	Testis
Tes	Testis (*Diacrisia obliqua*)
Tf	Terminal filament
Vd	Vas deferens
ve	Vas efferens
Vsm	Seminal vesicle
Vtl	Vitellarium
yo	Young oocytes
ys	Yolk spheres

Numbers Abbreviated in Plates

Accessory gland	01
Apical region of germarium	02
Bursal sac	03
Bulbus ejaculatorius	04
Carpus luteum	05
Cell debris collected in common oviduct.	06
Chorion	07
Common oviduct	08
Compound egg chamber	09
Compound oocytes	10
Debris of disintegrated cells	11
Disintigrating oocytes	12
Eggs	13
Ejaculatory duct	14
Empty ovariole/ Empty lateral oviduct	15
Epthelium	16
Follicular cells	17
Follicular plugs of pedicel	18
Germarium	19
Germinal vesicle	20
Homogenously granular ooplasm	21
Inner sheath	22
Interfollicular plugs	23
Lateral oviduct	24
Masses of climped chromatin	25
Mature oocytes	26
Mesadam	27
Multinucleated trophocytes	28
Nutritive cords	29
Oocytes	30
Outer sheath	31
Pedicel	32
Prefollicular cells	33
Reservoir of accessory gland	34
Spermathecal gland	35
Seminal vesicle	36
Spermatids	37
Spermatocytes	38
Spermatogonia	39
Spermatozoa	40
Terminal filament	41
Testes	42
Trophic core	43
Trophocytes	44
Tunica	45

Vacuoles	46
Vas efferens	47
Vasdeferens	48
Vitellarium	49
Yolk spheres	50
Young oocytes	51
Oocytes with sparse yolk spheres	52
Peritoneal sheath	53
Testicular follicles	54
Sperm cyst	55
Ovariole wall	56
Loop of ovariole	57
Compound egg chamber	58
Immature part of vitellarium	59
Malformed oocyte	60

PLATE-I

Incomplete moulting and malformation in wings of *Dysdercus cingulatus*

A= Different stages of normal *D. cingulatus*
B= Incomplete nymphal-nymphal (4^{th} to 5^{th} instar) moulting following the treatment of insecticides
C-E= Incomplete nymphal-adult moulting following the treatment of insecticides.
F-G= Adults with malformed wings.

PLATE-I

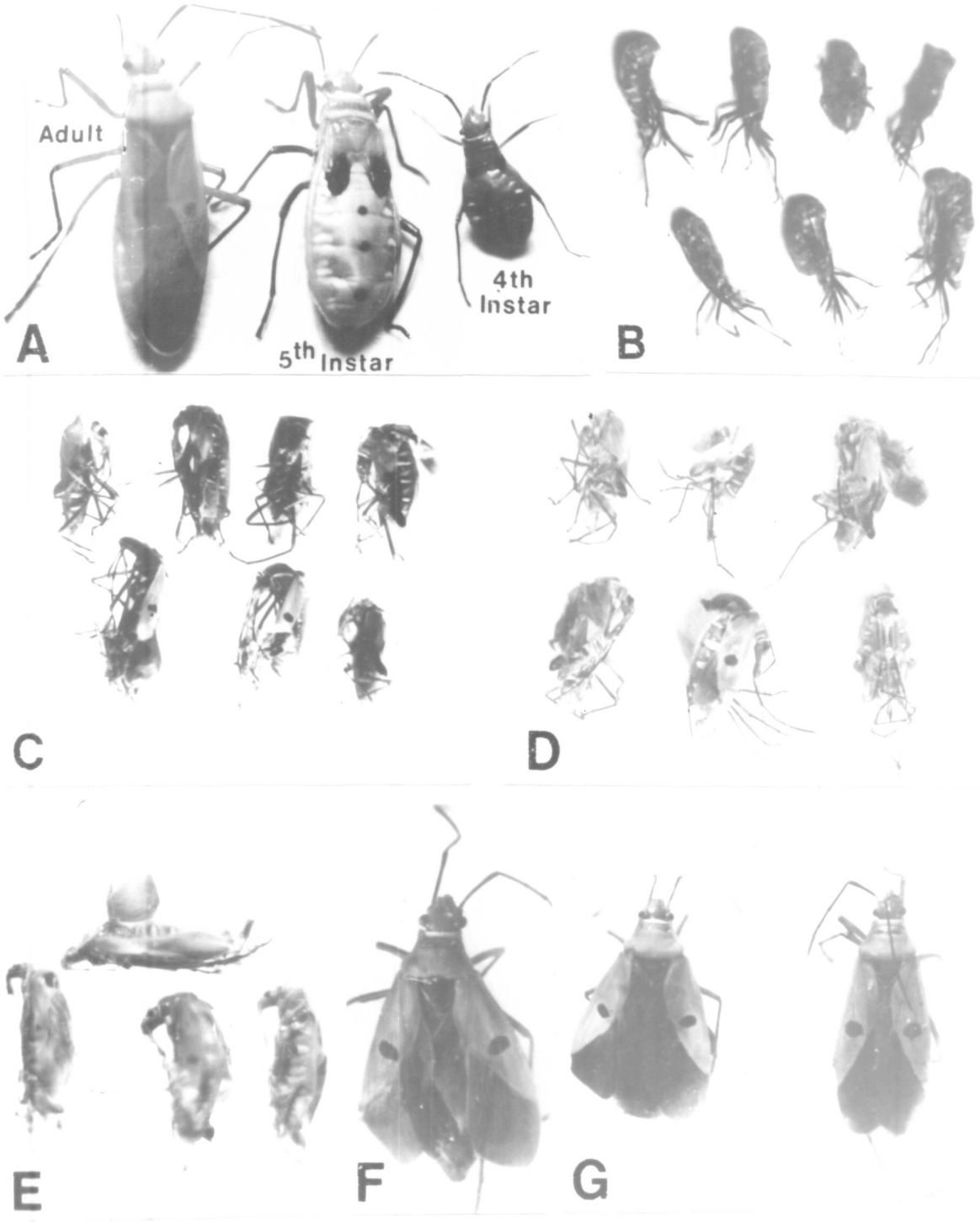

PLATE-II

Anatomical and histological pictures of the male and female reproductive organs of normal *Dysdercus cingulatus* (Camera lucida drawings)

A= Whole mount of left ovary
B= Whole mount of single ovariole.
C= Longitudinal section of the posterior region of the ovariole after oviposition.
D & E = Whole mount of male reproductive organs
F= Longitudinal section of the anterior region of the ovariole

PLATE-II

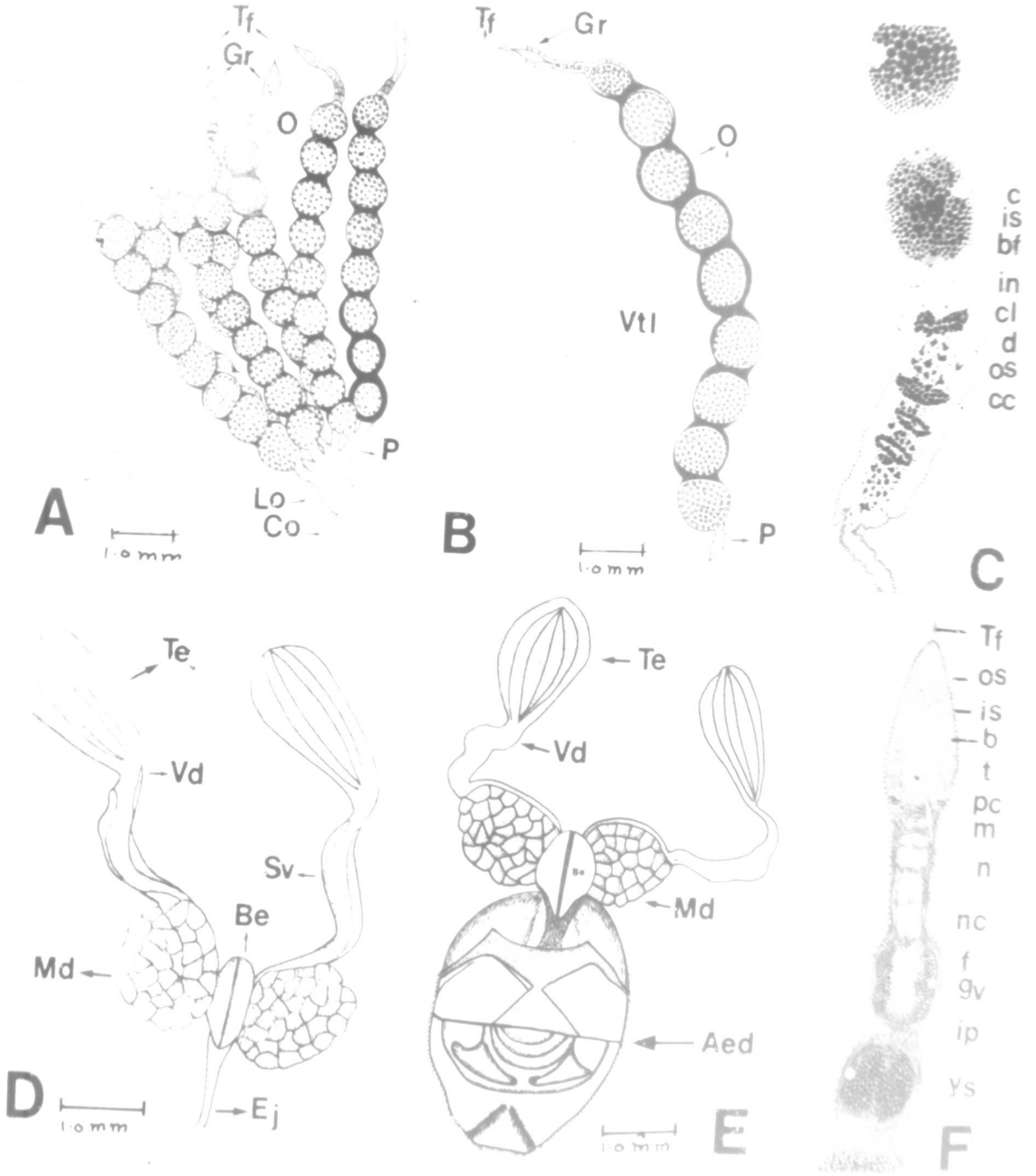
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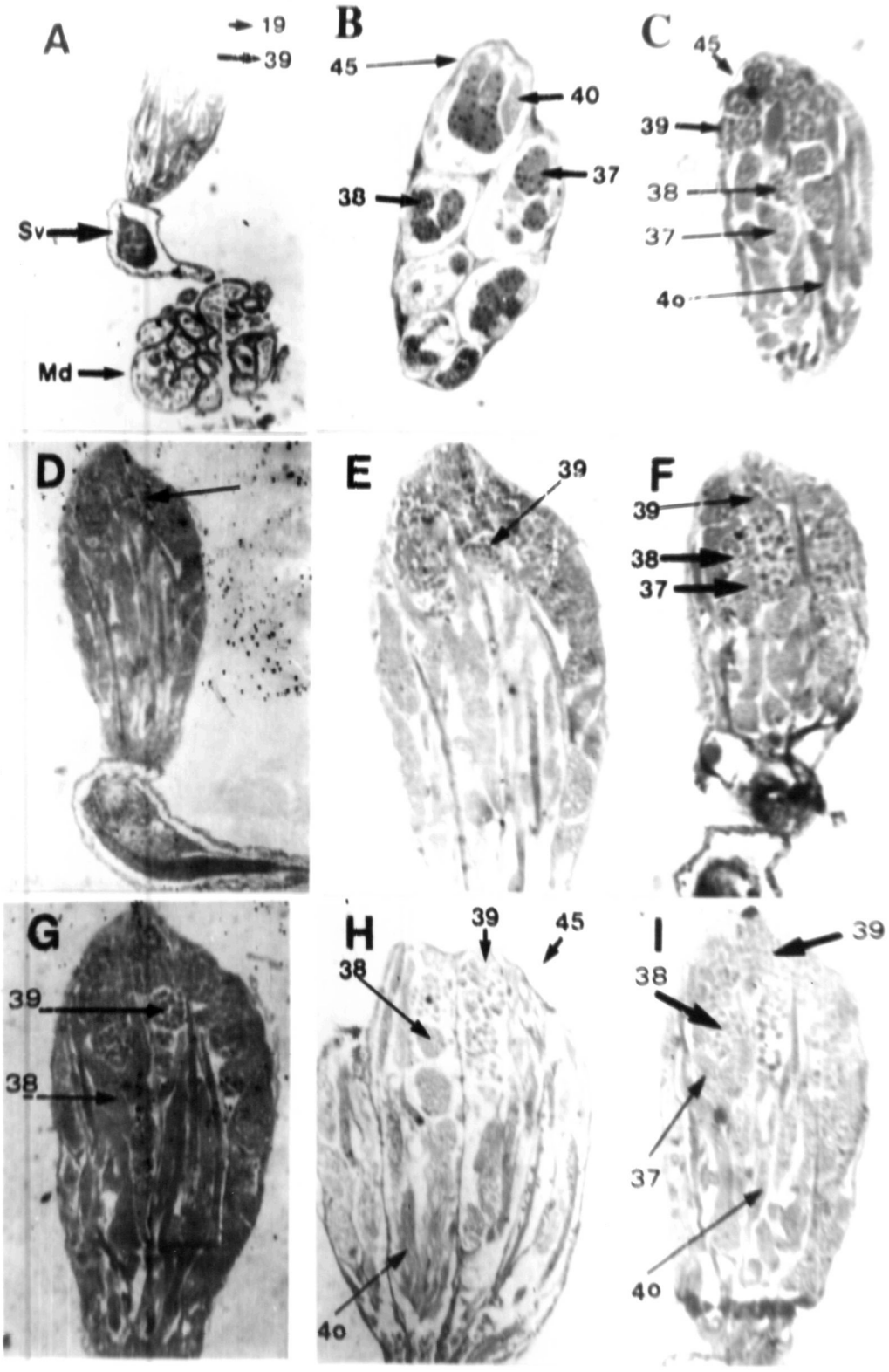
PLATE-III

Histological pictures of the male reproductive organs of *Dysdercus cingulatus* emerged from normal and treated nymphs.

A= Longitudinal section of testis of five days old normal male along with seminal vesicle and mesadene
B = Transverse section of the testis of five days old normal male.
C = Longitudinal section of the testis of five days old normal male.
D = Longitudinal section of the testis of five days old male affected with acephate.
E = Longitudinal section of the testis of five days old male affected with ethion.
F = Longitudinal section of the testis of five days old male affected with dichlorvos.
G = Longitudinal section of the testis of five days old male affected with furadan.
H = Longitudinal section of the testis of five days old male affected with carbaryl.
I = Longitudinal section of the testis of five days old male affected with aminocarb.

PLATE-III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45
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4o
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39
38
37
4o

PLATE-IV

Anatomical and histological damages in the ovaries of *Dysdercus cingulatus* females emerged from 4th and 5th instar treated nymphs following the topical application of higher selected sublethal concentrations (0.002, 0.001and 0.0008%) of acephate.

A= Longitudinal section through the basal part of the vitellarium of five days old female emerged from 5th instar treated nymphs.
B= Longitudinal section through the middle part of the vitellarium of ten days old female emerged from 4th instar treated nymphs.
C= Longitudinal section through the middle part of the vitellarium of five days old female emerged from 4th instar treated nymphs.
D= Longitudinal section through the germarium of ten days old female emerged from 4th instar treated nymphs.
E= Longitudinal section through the middle part of the vitellarium of five days old female emerged from 4th instar treated nymphs.
F= Longitudinal section through the upper part of the vitellarium of ten days old female emerged from 4th instar treated nymphs.
G= Resorption of oocytes in ten days old female emerged from 4th instar treated nymphs.
H= Ovary of five days old female emerged from 4th instar treated nymphs.
I= Ovary of five days old female emerged from 5th instar treated nymphs.
J= Ovary of ten days old female emerged from 4th instar treated nymphs.
K= Ovary of five days old female emerged from 5th instar treated nymphs.
L= Ovary of twenty days old female emerged from 5th instar treated nymphs.

PLATE-IV

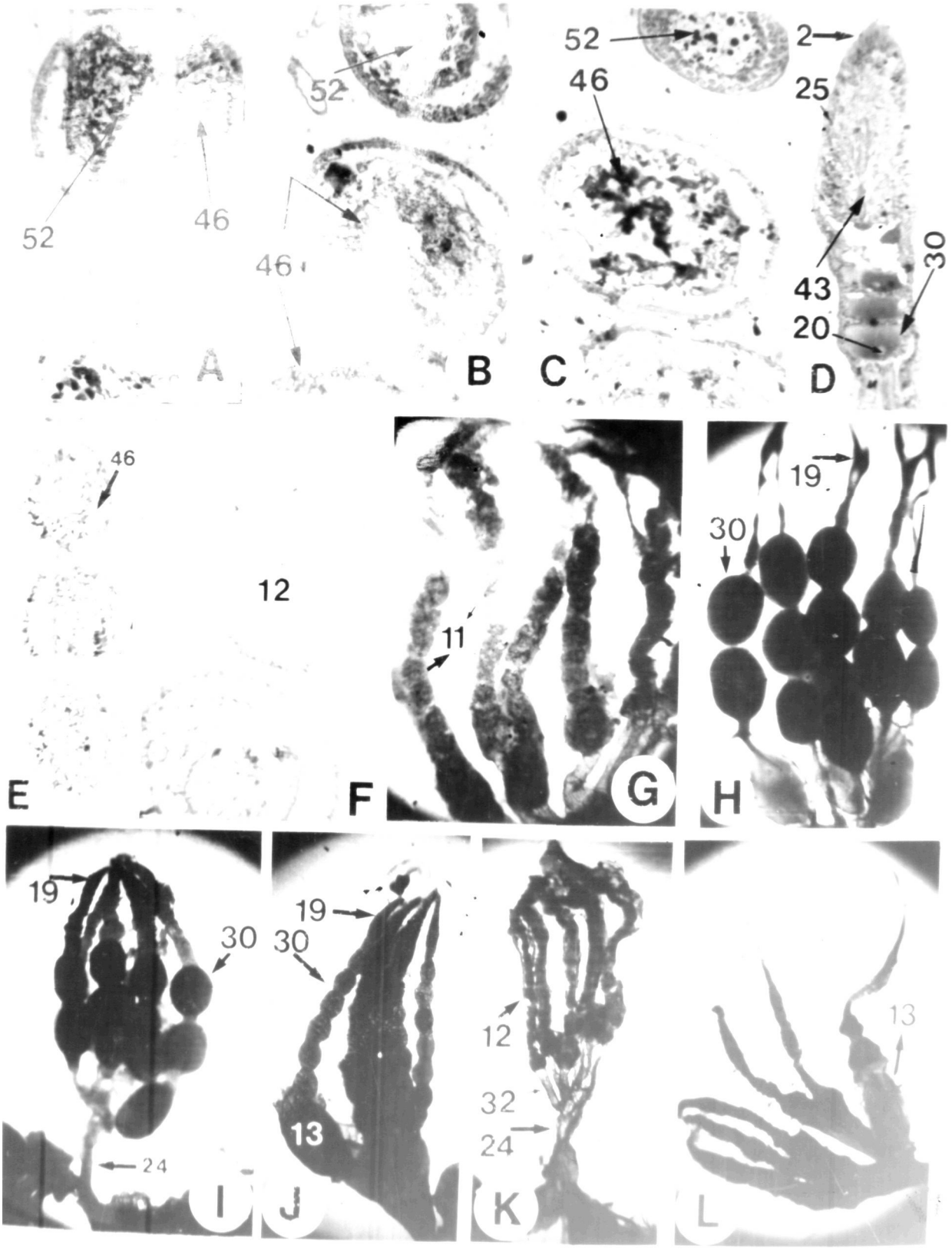
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PLATE-V

Anatomical and histological damages in the ovaries of *Dysdercus cingulatus* females emerged from 4th and 5th instar treated nymphs following the topical application of higher selected sublethal concentrations (0.006, 0.004 and 0.002%) of ethion.

A,B & C= Longitudinal section through the middle part of the vitellarium of five days old female emerged from 5th instar treated nymphs.

D= Longitudinal section through the germarium of ten days old female emerged from the 4th instar treated nymphs.

E= Ovary of ten days old female emerged from 4th instar treated nymphs.

F= Ovary of five days old female emerged from 4th instar treated nymphs.

G= Ovary of ten days old female emerged from 4th instar treated nymphs.

H= Ovary of five days old female emerged from 5th instar treated nymphs.

I= Ovary of ten days old female emerged from 5th instar treated nymphs.

J= Ovary of twenty days old female emerged from 4th instar treated nymphs.

PLATE-V

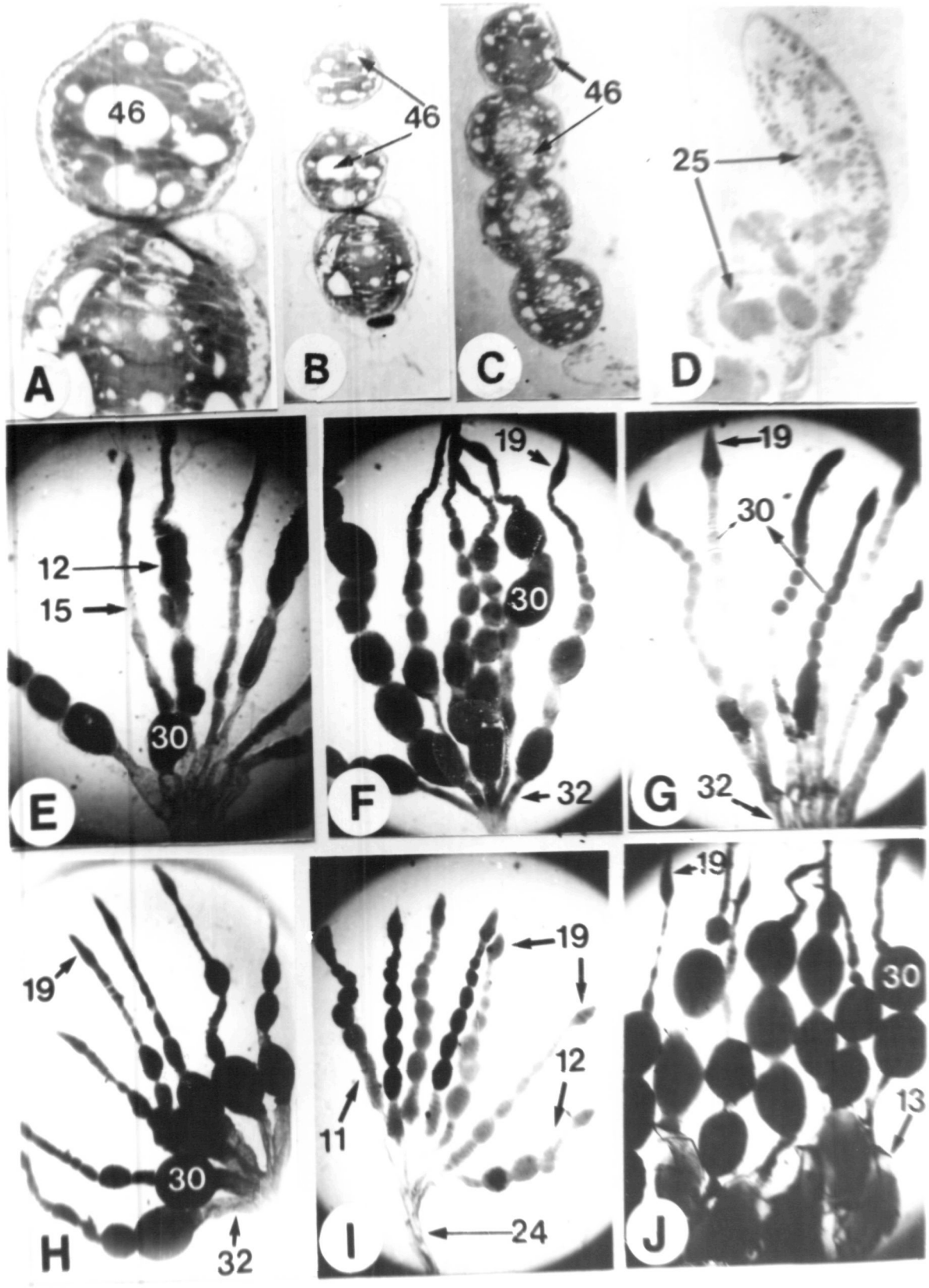
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PLATE VI

Anatomical and histological damages in the ovaries of *Dysdercus cingulatus* females emerged from 4th and 5th instar treated nymphs following the topical application of higher selected sublethal concentrations (0.01 and 0.008%) of dichlorvos.

A= Longitudinal section through the middle part of the vitellarium of ten days old female emerged from 4th instar treated nymphs.
B= Longitudinal section through the basal part of the vitellarium of ten days old female emerged from 4th instar treated nymphs.
C= Longitudinal section through the germarium of five days old female emerged from 4th instar treated nymphs.
D= Longitudinal section through the basal part of the vitellarium of five days old female emerged from 4th instar treated nymphs.
E= Ovary of ten days old female emerged from 4th instar treated nymphs.
F= Ovary of five days old female emerged from 4th instar treated nymphs.
G= Longitudinal section through the basal part of the vitellarium of five days old female emerged from 5th instar treated nymphs.
H= Ovary of five days old female emerged from 5th instar treated nymphs.
I= Ovary of ten days old female emerged from 5th instar treated nymphs.

PLATE-VI

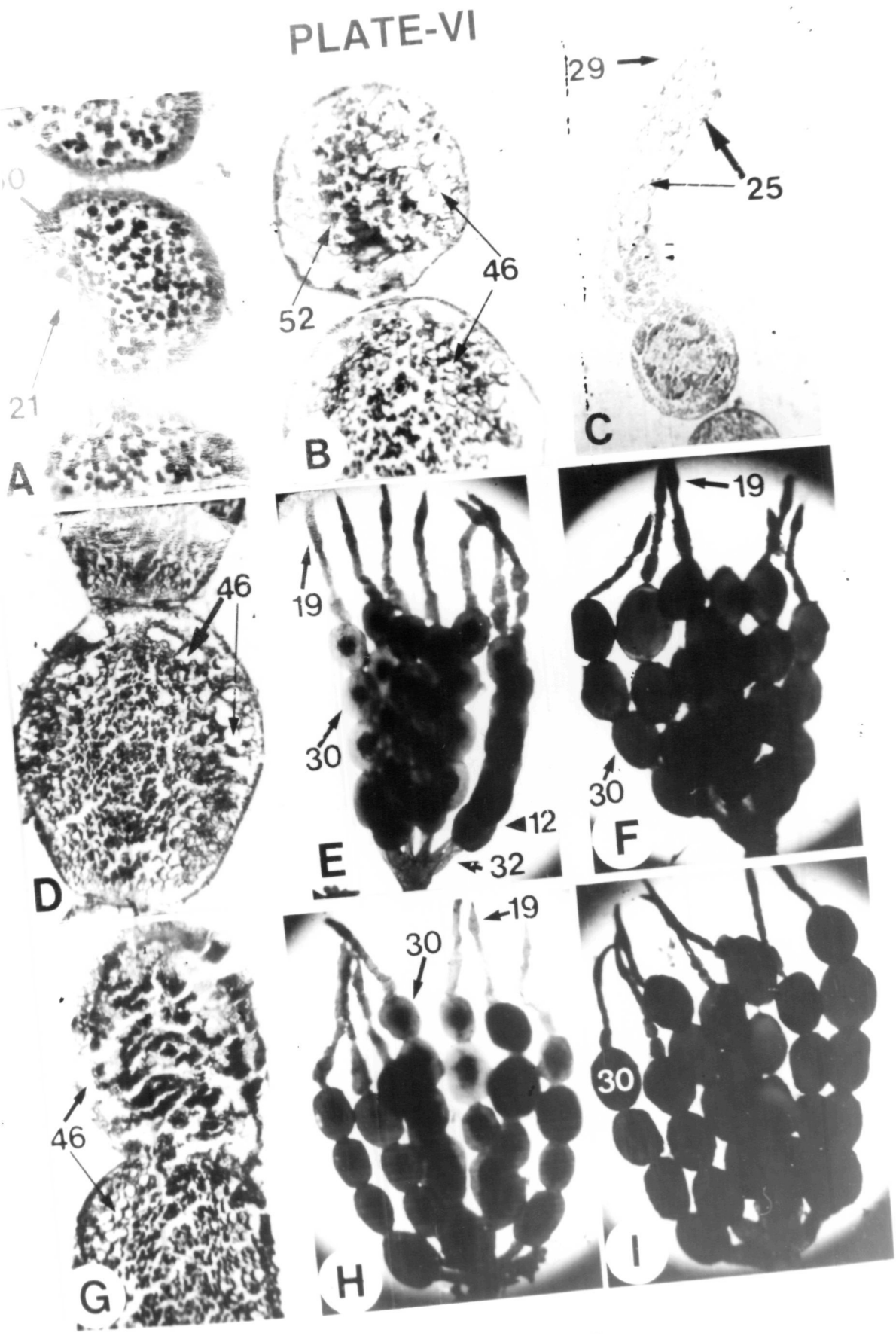

PLATE VII

Anatomical and hist logical damages in the ovaries of *Dysdercus cingulatus* females emerged from 4th and 5th instar treated nymphs following the topical application of higher selected sublethal concentrations (0.001, 0.0008, 0.0006%) of furadan.

A= Longitudinal section through the middle part of the vitellarium of five days old female emerged from 4th instar treated nymphs.
B= Longitudinal section through the middle part of the vitellarium of five days old female emerged from 5th instar treated nymphs.
C= Longitudinal section through the basal part of the vitellarium of ten days old female emerged from 5th instar treated nymphs.
D= Longitudinal section through the germarium of five days old female emerged from 4th instar treated nymphs.
E= Ovary of five days old female emerged from 4th instar treated nymphs.
F= Ovary of ten days old female emerged from 4th instar treated nymphs.
G= Ovary of ten days old female emerged from 4th instar treated nymphs.
H= Ovary of five days old female emerged from 5th instar treated nymphs.
I= Ovary of five days old female emerged from 5th instar treated nymphs.
J= Ovary of ten days old female emerged from 5th instar treated nymphs.

PLATE-VII

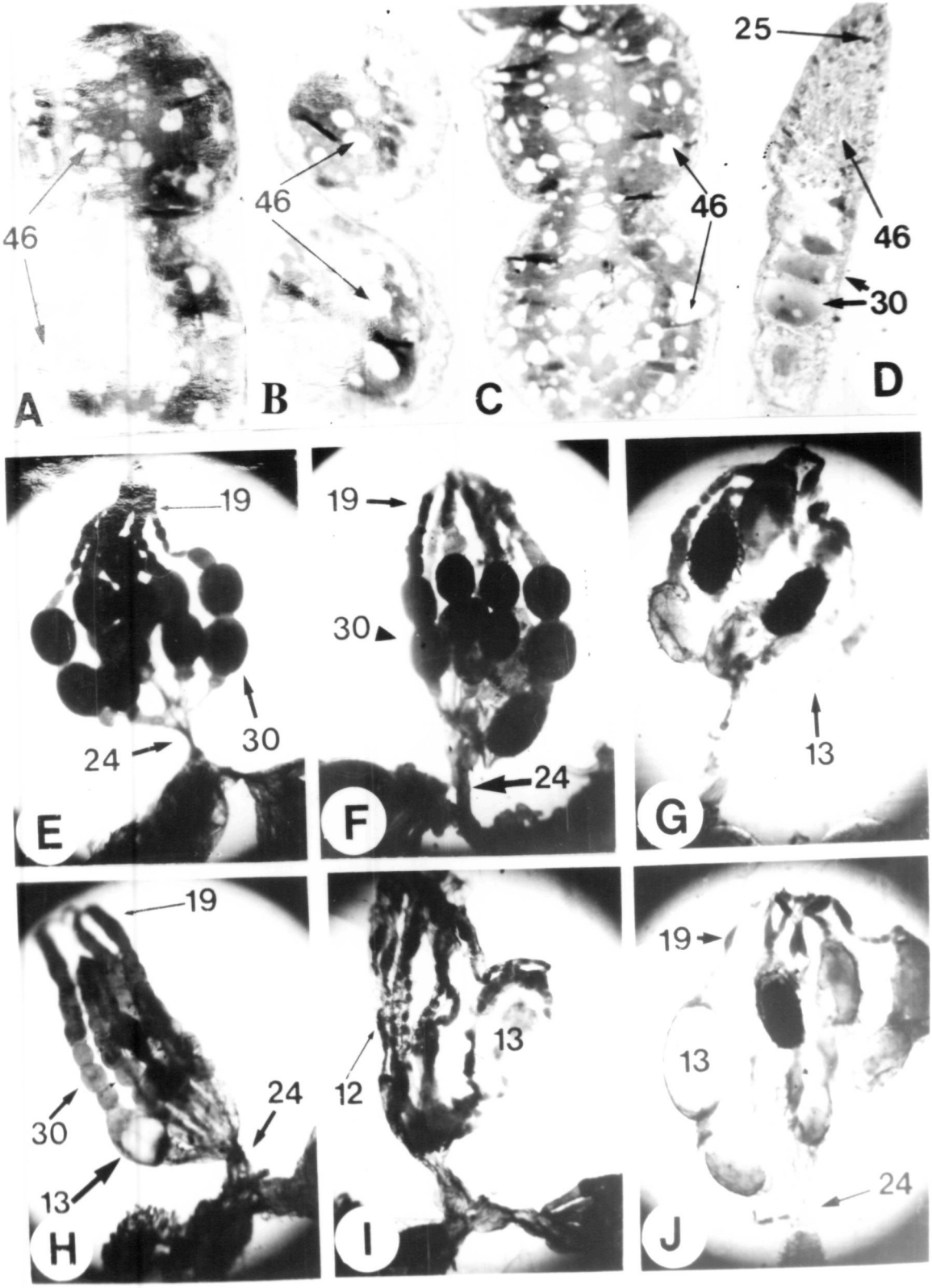
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PLATE VIII

Anatomical and histological damages in the ovaries of *Dysdercus cingulatus* females emerged from 4th and 5th instar treated nymphs following the topical application of higher selected sublethal concentrations (0.0025 and 0.002%) of carbaryl.

A= Longitudinal section through the middle part of the vitellarium of ten days old female emerged from 5th instar treated nymphs.
B= Longitudinal section through the middle part of the vitellarium of five days old female emerged from 4th instar treated nymphs.
C= Longitudinal section through the germarium of five days old female emerged from 4th instar treated nymphs.
D= Ovary of five days old female emerged from 4th instar treated nymphs.
E= Ovary of five days old female emerged from 4th instar treated nymphs.
F= Ovary of ten days old female emerged from 4th instar treated nymphs.
G= Ovary of five days old female emerged from 5th instar treated nymphs.
H= Ovary of ten days old female emerged from 5th instar treated nymphs.
I= Ovary of five days old female emerged from 5th instar treated nymphs.

PLATE-VIII

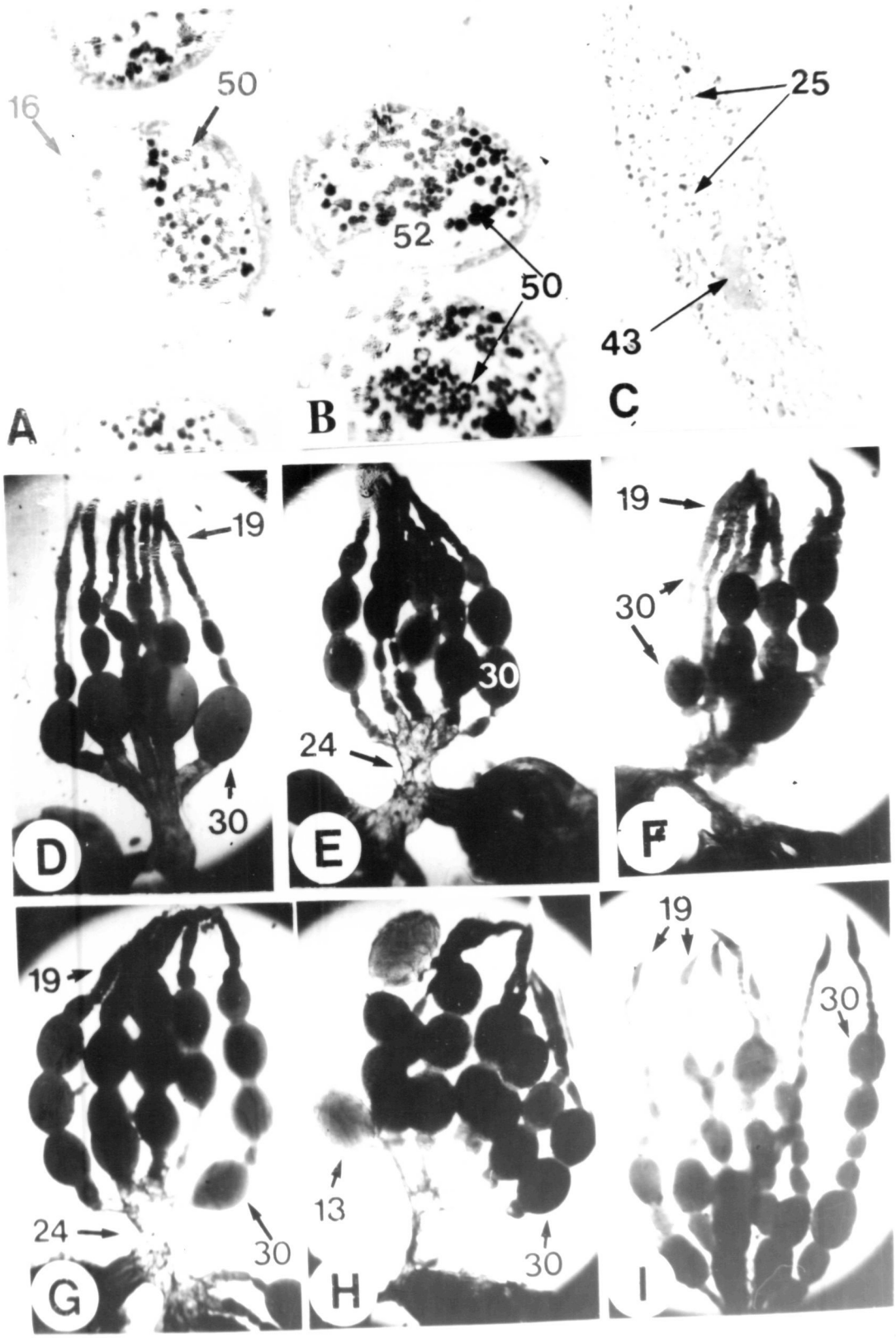

PLATE-IX

Anatomical and histological damages in the ovaries of *Dysdercus cingulatus* females emerged from 4th and 5th instar treated nymphs following the topical application of higher selected sublethal concentrations (0.004, 0.002 and 0.001%) aminocarb.

A= Longitudinal section through the middle part of the vitellarium of five days old female emerged from 4th instar treated nymphs.
B= Longitudinal section through the basal part of the vitellarium of ten days old female emerged from 4th instar treated nymphs.
C= Longitudinal section through the middle part of the vitellarium of five days old female emerged from 5th instar treated nymphs.
D= Longitudinal section through the germarium of five days old female emerged from 5th instar treated nymphs.
E= Ovary of five days old female emerged from 4th instar treated nymphs.
F= Ovary of five days old female emerged from 4th instar treated nymphs.
G= Ovary of ten days old female emerged from 4th instar treated nymphs.
H= Longitudinal section through the basal part of the vitellarium of ten days old female emerged from 5th instar treated nymphs.
I= Ovary of twenty days old female emerged from 4th instar treated nymphs.
J= Ovary of twenty days old female emerged from 5th instar treated nymphs.
K= Ovary of five days old female emerged from 5th instar treated nymphs.

PLATE-IX

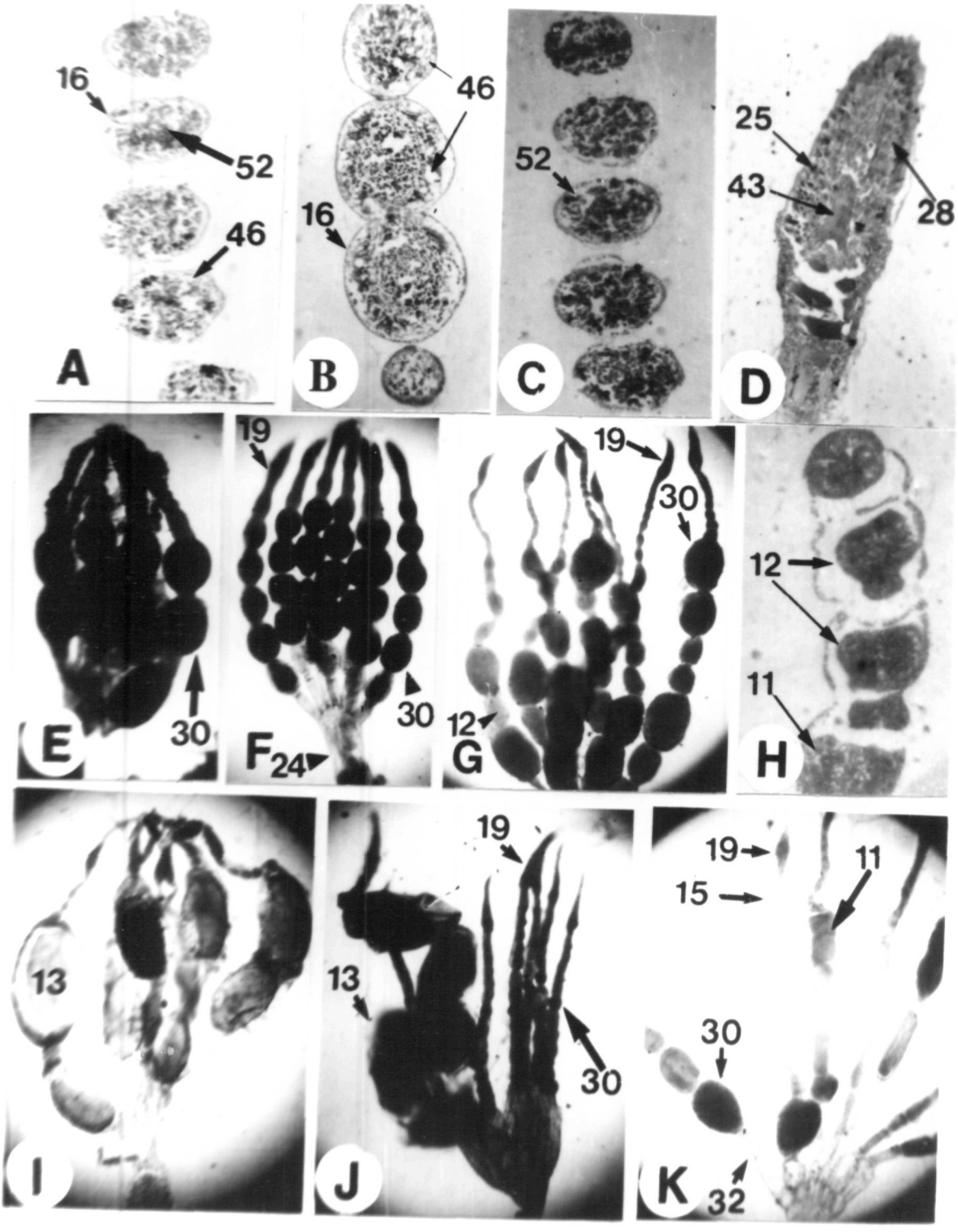
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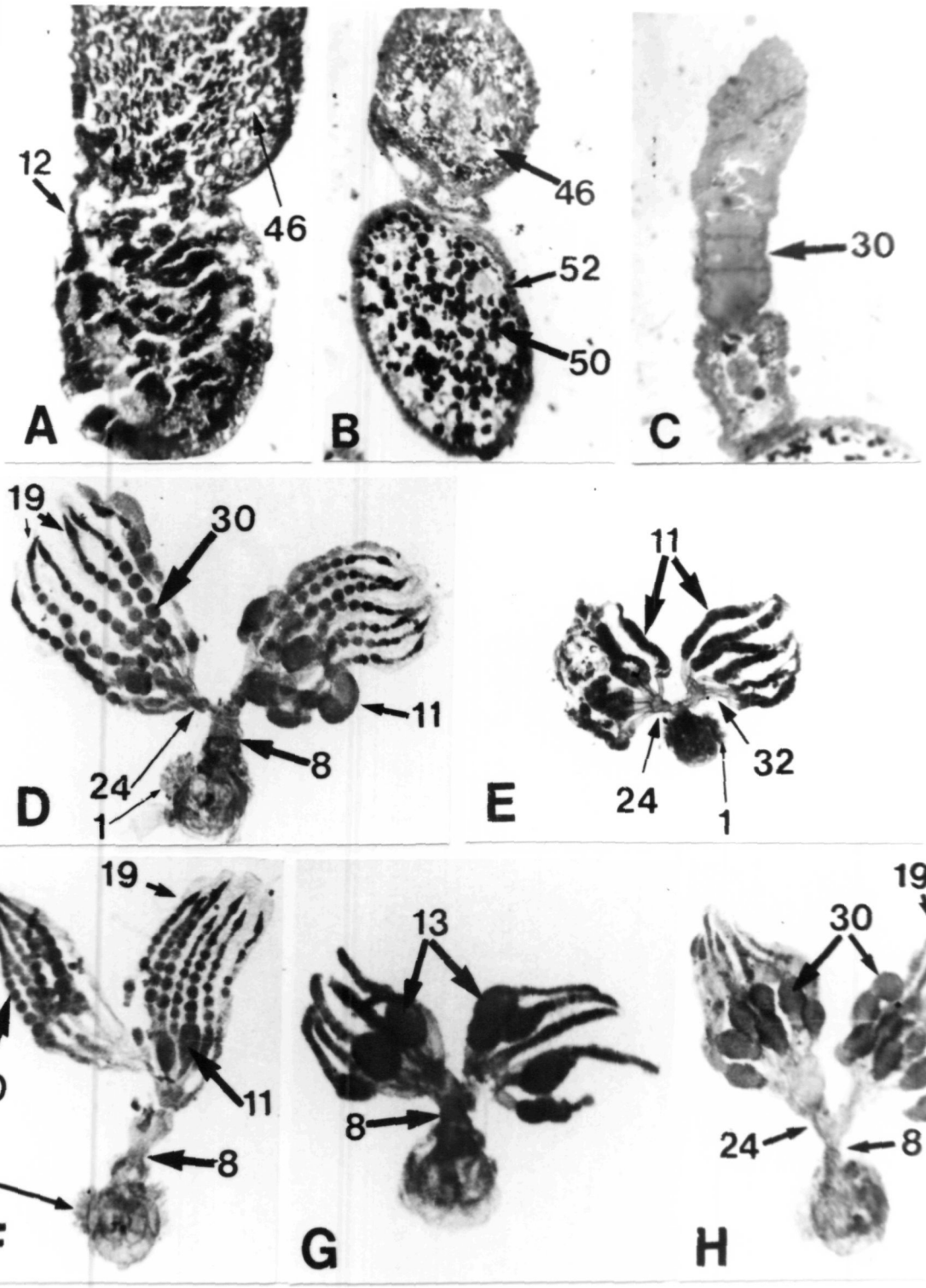
PLATE-X

Anatomical and histological damages in the ovaries of *D. cingulatus* females emerged from 4th and 5th instar treated nymphs.

A= Longitudinal section through the basal part of the vitellarium of five days old female emerged from 4th instar nymphs treated with 0.002% acephate.
B= Longitudinal section through the middle part of the vitellarium of five days old female emerged from 4th instar nymphs treated with 0.002% acephate.
C= Longitudinal section through the germarium of ten days old female emerged from 5th instar nymphs treated with 0.001% furadan.
D= Whole mount of the female reproductive system of five days old female emerged from 4th instar nymphs treated with 0.006% ethion.
E= Whole mount of the female reproductive system of five days old female emerged from 5th instar nymphs treated with 0.001% furadan.
F= Whole mount of the female reproductive system of five days old female emerged from 5th instar nymphs treated with 0.002% acephate.
G= Whole mount of the female reproductive system of twenty days old female emerged from 4th instar nymphs treated with 0.001% furadan.
H= Whole mount of the female reproductive system of ten days old female emerged from 4th instar nymphs treated with 0.001% furadan.

PLATE-X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8
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30
24
8
H

PLATE-XI

Incomplete larval-pupal transformation, abnormal pupation, incomplete adult emergence and malformation in the wings of *Diacrisia obliqua.*

A= Normal adult (Female).

B & C= Incomplete adult emergence following the topical application of different insecticides.

D= Incomplete larval-pupal transformation following the topical application of different insecticides.

E= (f & g) normal pupae, (a,b,c,d,e,h,i,j,k,) abnormal pupae following the topical application of different insecticides.

F= Malformation in the wings of the adults following the topical application of different insecticides.

G= Incomplete adult emergence following the topical application of different insecticides.

PLATE-XI

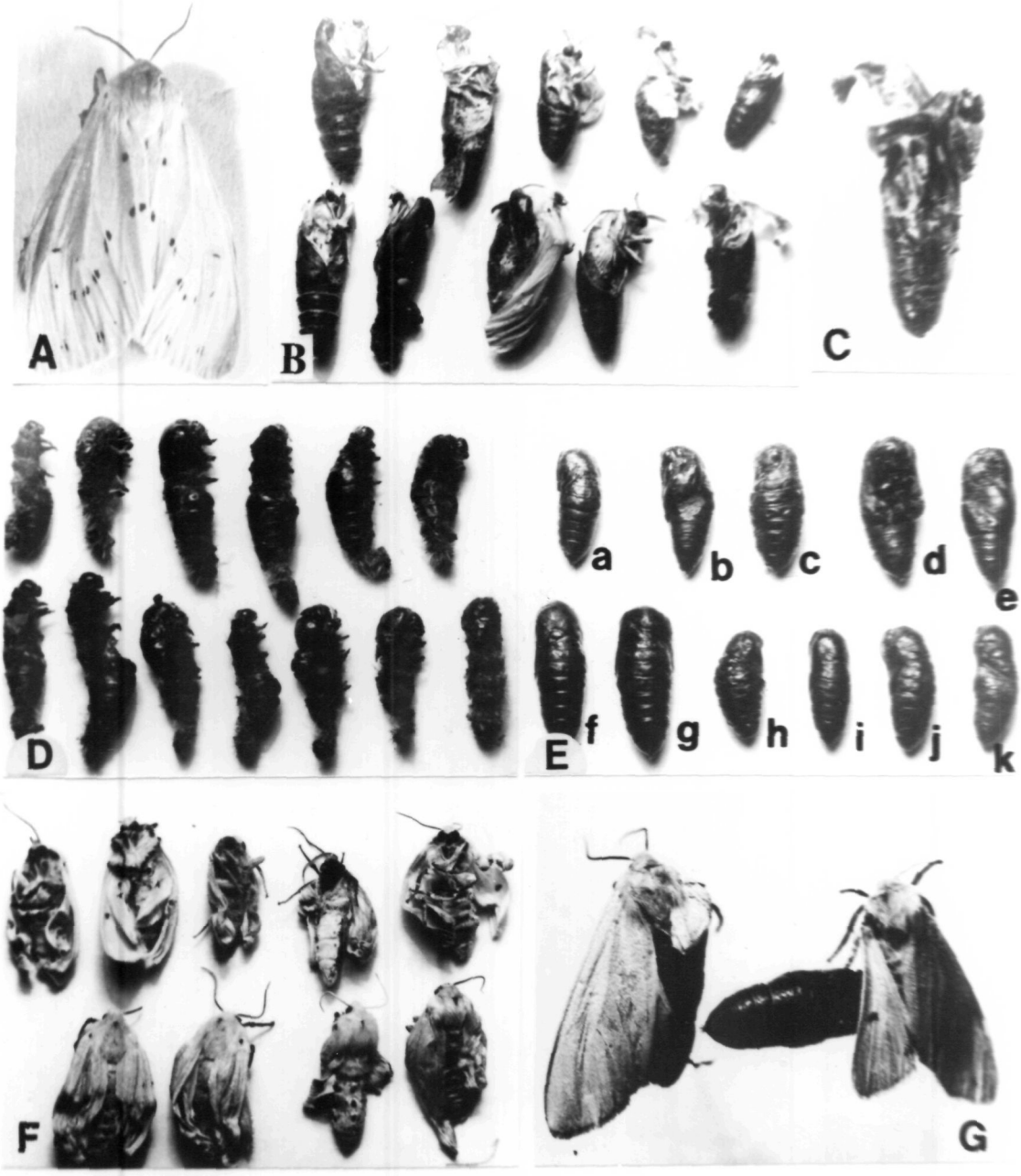
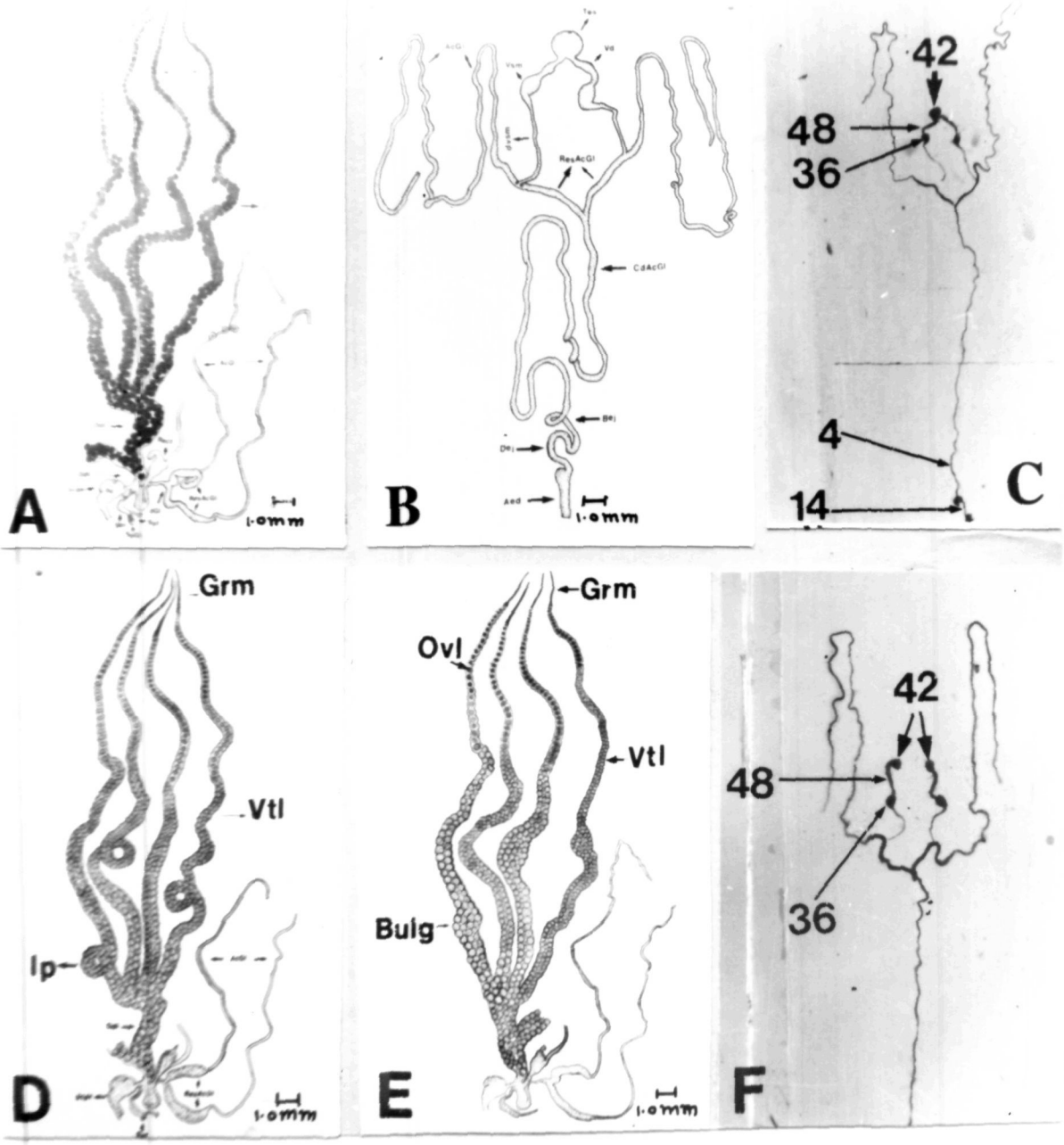


PLATE-XII

Anatomical and histological pictures of the male and female reproductive organs of *Diacrisia obliqua*.

A= Whole mount of the right ovary (Camera lucida drawing).
B= Whole mount of the male reproductive organs (Camera lucida drawing).
C= Whole mount of the male reproductive organs.
D= Whole mount of right ovary of female the affected with insecticides showing loop formation in the ovarioles.
E= Whole mount of left ovary of the affected female showing bulging (compound egg chamber) in the ovarioles.
F= Whole mount of the male reproductive system the affected with 0.001% furadan showing incomplete fusion of the two testes.

PLATE-XII


A
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4
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Grm
Ovl
Vtl
Bulg
E
1·0mm
42
48
36
F

PLATE -XIII

Histological picture of the male reproductive organs of *Diacrisia obliqua* emerged from 5th and 6th instar treated larvae.

A= Longitudinal section through the testis of the normal male.

B= Longitudinal section through the testis of the affected male emerged from acephate treated 5th instar larvae.

C= Longitudinal section through the testis of the affected male emerged from ethion treated 5th instar larvae.

D= Longitudinal section through the testis of the affected male emerged from dichlorvos treated 6th instar larvae.

E= Longitudinal section through the testis of the affected male emerged from furadan treated 5th instar larvae.

F= Longitudinal section through the testis of the affected male emerged from carbaryl treated 5th instar larvae.

G & H=Longitudinal section through the testis of the affected male emerged from aminocarb treated 6th instar larvae.

PLATE-XIII

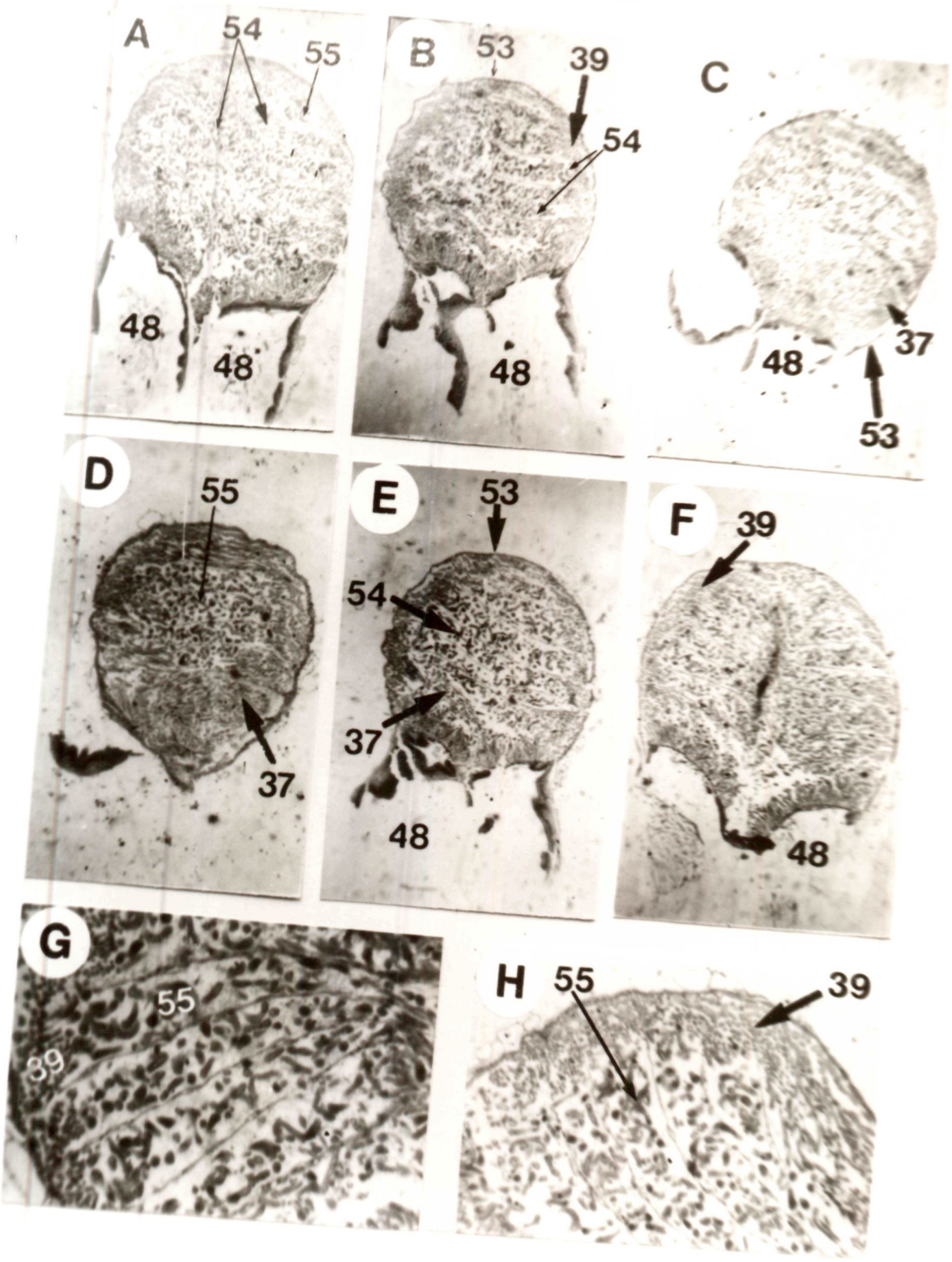
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PLATE-XIV

Anatomical and histological damages in the ovaries of *Diacrisia obliqua* females emerged from 5th and 6th instar treated larvae following the topical application of higher selected sublethal concentrations (0.02, 0.04 and 0.06%) of acephate.

A= Longitudinal section through the middle part of the vitellarium of the affected female emerged from 6th instar treated larvae.

B= Longitudinal section through the middle part of the vitellarium of the affected female emerged from 5th instar treated larvae.

C= Uncoiled whole reproductive system of the affected female emerged from 5th instar treated larvae.

D= Longitudinal section through upper part of the vitellarium of the affected female emerged from 5th instar treated larvae.

E & F= Coiled whole reproductive system of the affected females emerged from 5th instar treated larvae.

G-I= Coiled whole reproductive system of the affected females emerged from 6th instar treated larvae.

PLATE-XIV

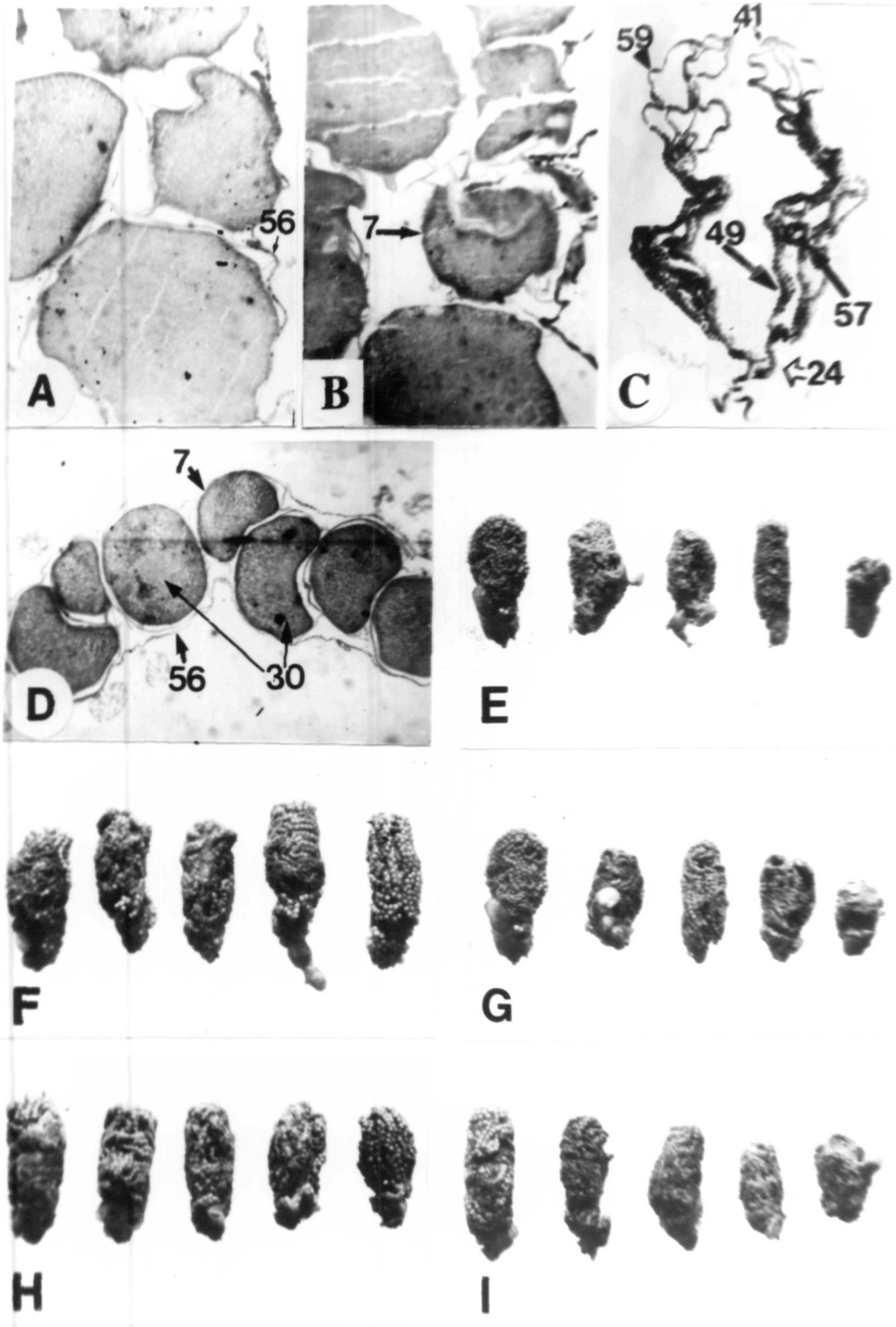


PLATE-XV

Anatomical and histological damages in the ovaries of *Diacrisia obliqua* females emerged from 5th and 6th instar treated larvae following the topical application of higher selected sublethal concentrations (0.6, 0.4 and 0.2%) of ethion

A= Longitudinal section through the upper part of the vitellarium of the affected female emerged from 6th instar treated larvae.

B= Longitudinal section through the middle part of the vitellarium of the affected female emerged from 5th instar treated larvae.

C= Uncoiled whole reproductive system of affected female emerged from 5th instar treated larvae.

D= Longitudinal section through the basal part of the vitellarium of the affected female emerged from 6th instar treated larvae.

E-G= Coiled whole reproductive system of the affected females emerged from 5th instar treated larvae.

H-I= Coiled whole reproductive system of the affected females emerged from 6th instar treated larvae.

PLATE-XV

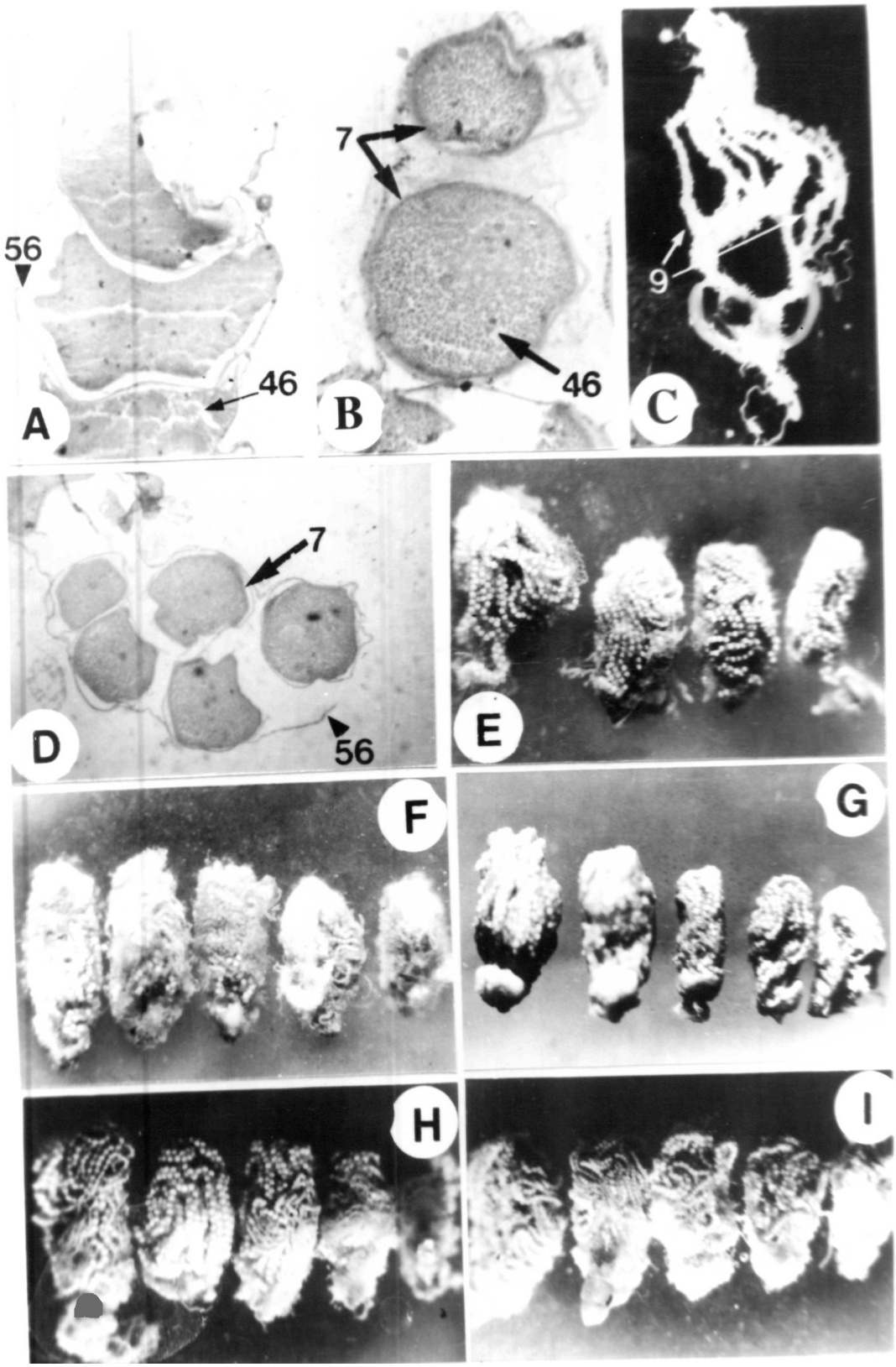


PLATE-XVI

Anatomical and histological damages in the ovaries of *Diacrisia obliqua* females emerged from 5th and 6th instar treated larvae following the topical application of higher selected sublethal concentrations (0.02, 0.04 and 0.06%) of acephate.

A= Longitudinal section through the middle part of the vitellarium of the affected female emerged from 5th instar treated larvae.

B= Longitudinal section through the basal part of the vitellarium of the affected female emerged from 6th instar treated larvae.

C= Uncoiled whole reproductive system of the affected female emerged from 5th instar treated larvae.

D= Longitudinal section through the basal part of the vitellarium of the affected female emerged from 5th instar treated larvae.

E,F,& I= Coiled whole reproductive system of the affected females emerged from 5thinstar treated larvae.

G & H= Coiled whole reproductive system of the affected females emerged from 6th instar treated larvae.

PLATE-XVI

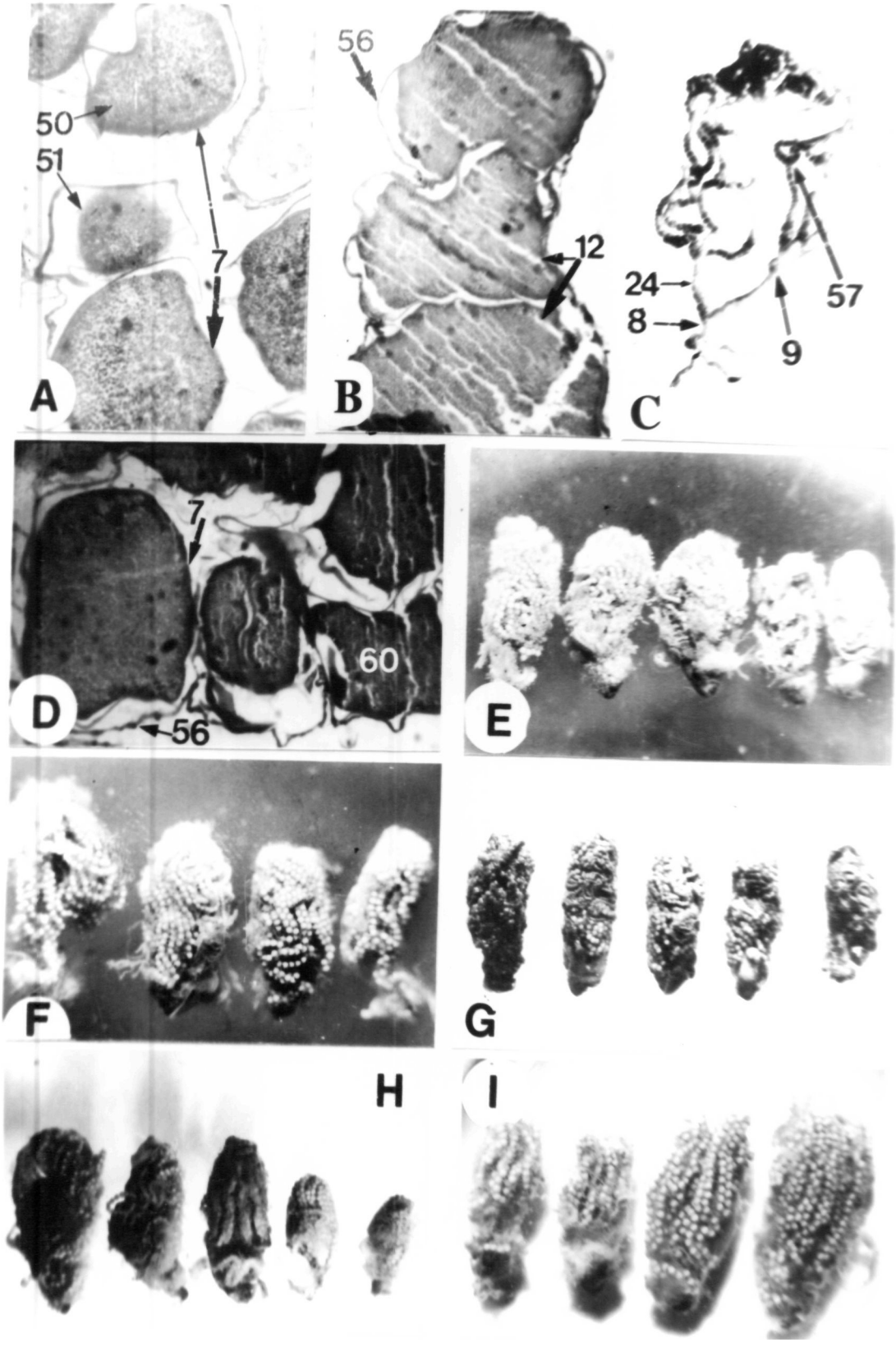


PLATE-XVII

Anatomical and histological damages in the ovaries of *Diacrisia obliqua* females emerged from 5th and 6th instar treated larvae following the topical application of higher selected sublethal concentrations (0.08, 0.06 and 0.04%) of furadan.

A= Longitudinal section through the middle part of the vitellarium of the affected female emerged from 6th instar treated larvae.

B= Longitudinal section through the middle part of the vitellarium of the affected female emerged from 5th instar treated larvae.

C= Uncoiled whole reproductive system of the affected female emerged from 5th instar treated larvae.

D= Longitudinal section through the upper part of the vitellarium of the affected female emerged from 6th instar treated larvae.

E-G= Coiled whole reproductive system of the affected females emerged from 5th instar treated larvae.

H & I= Coiled whole reproductive system of the affected females emerged from 6th instar treated larvae.

PLATE-XVII

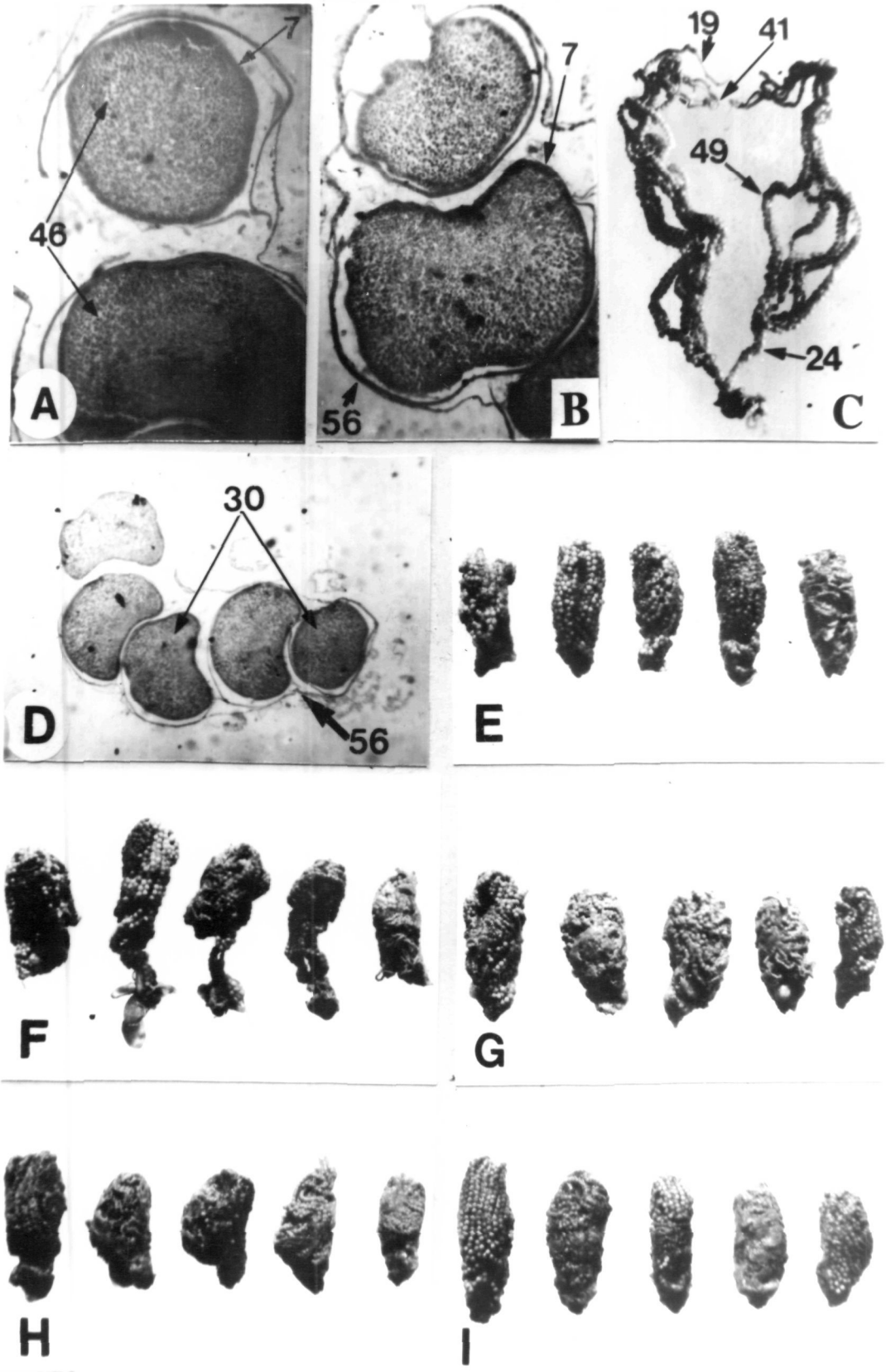


PLATE-XVIII

Anatomical and histological damages in the ovaries of *Diacrisia obliqua* females emerged from 5th and 6th instar treated larvae following the topical application of higher selected sublethal concentrations (0.15, 0.1 and 0.08%) of carbaryl.

A= Longitudinal section through the basal part of the vitellarium of the affected female emerged from 5th instar treated larvae.

B= Longitudinal section through the basal part of the vitellarium of the affected female emerged from 5th instar treated larvae.

C= Uncoiled whole reproductive system of the affected female emerged from 5th instar treated larvae.

D= Longitudinal section through the upper part of the vitellarium of the affected female emerged from 6th instar treated larvae.

E & F= Coiled whole reproductive system of the affected females emerged from 5th instar treated larvae.

G,H & I= Coiled whole reproductive system of the affected females emerged from 6th instar treated larvae.

PLATE-XVIII

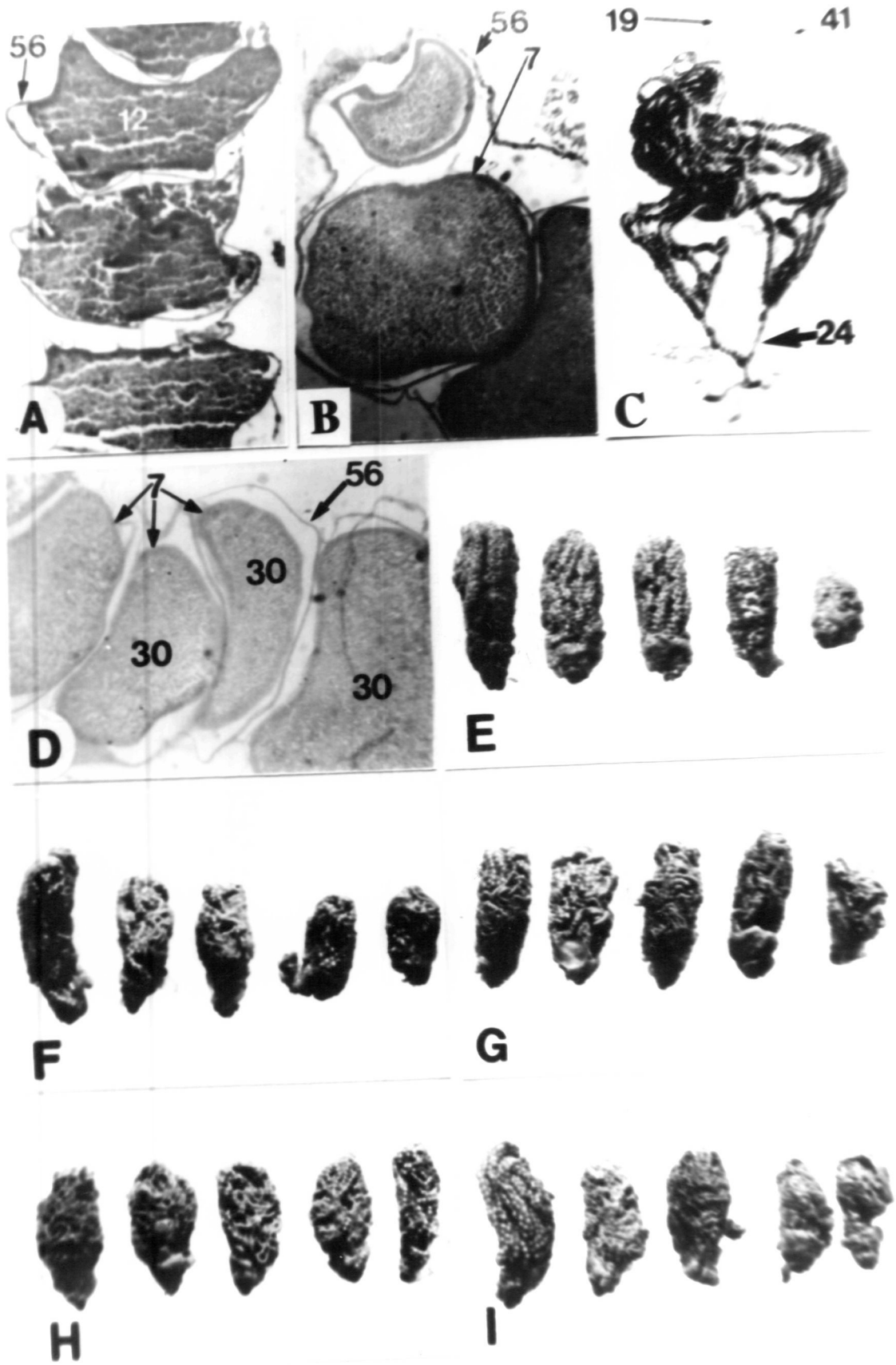


PLATE-XIX

Anatomical and histological damages in the ovaries of *Diacrisia obliqua* females emerged from 5th and 6th instar treated larvae following the topical application of higher selected sublethal concentrations (0.25, 0.2 and 0.15%) of aminocarb.

A= Longitudinal section through the basal part of the vitellarium of the affected female emerged from 6th instar treated larvae.

B= Longitudinal section through the middle part of the vitellarium of the affected female emerged from 5th instar treated larvae.

C= Uncoiled whole reproductive system of affected female emerged from 5th instar treated larvae.

D= Longitudinal section through the upper part of the vitellarium of the affected female emerged from 5th instar treated larvae.

E & H= Coiled whole reproductive system of the affected females emerged from 5th instar treated larvae.

G & I= Coiled whole reproductive system of the affected females emerged from 6th instar treated larvae.

PLATE-XIX

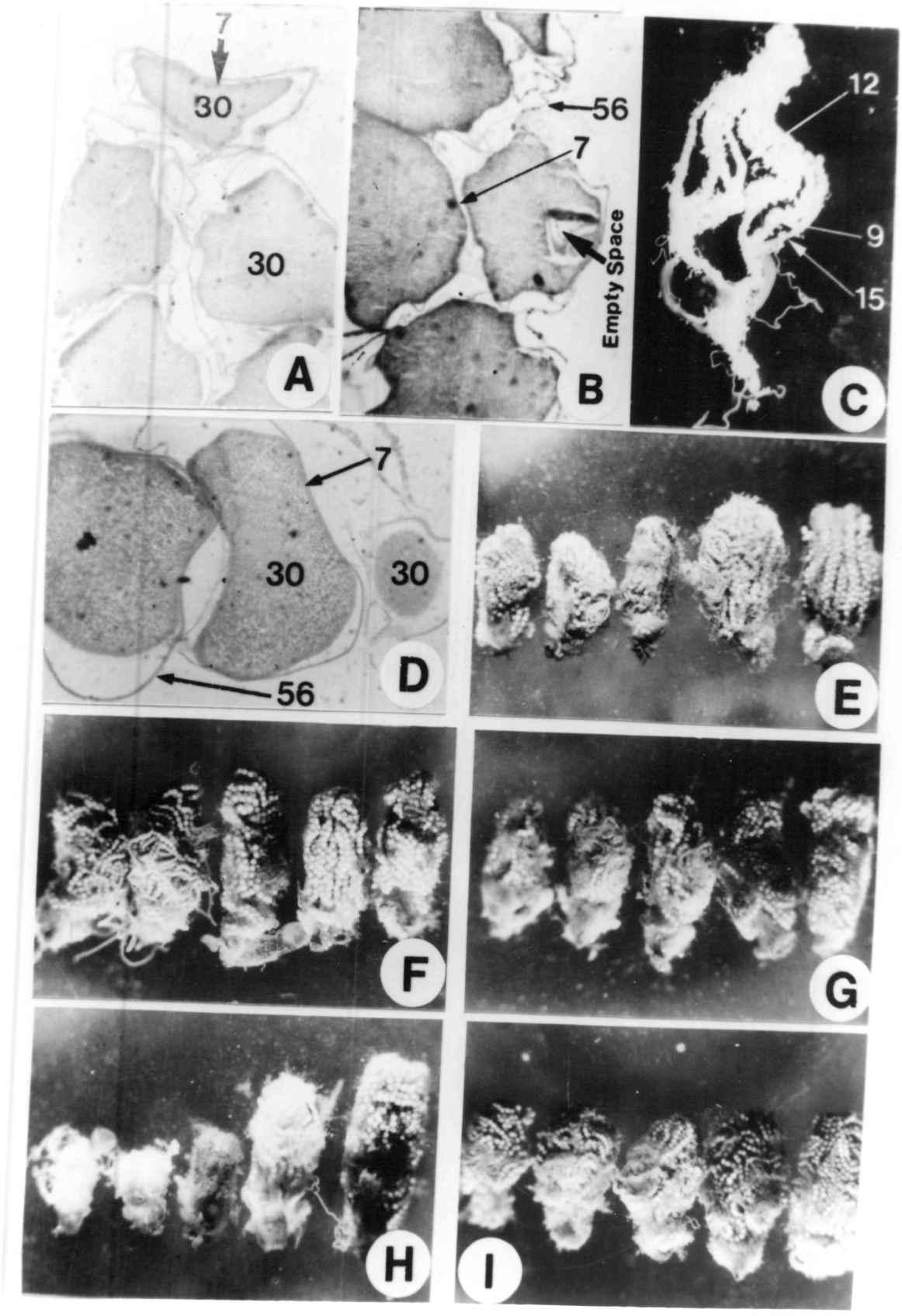


PLATE- XX

Anatomical structures of the severely affected ovaries of *Diacrisia obliqua* females emerged from treated larvae.

A= Whole mount of the lower half portion of the uncoiled reproductive system of the normal female.

B= Whole mount of the uncoiled reproductive system of the affected female emerged from furadan treated 5th instar larvae.

C= Ovarioles of the affected female emerged from dichlorvos treated 5th instar larvae showing compound egg chamber.

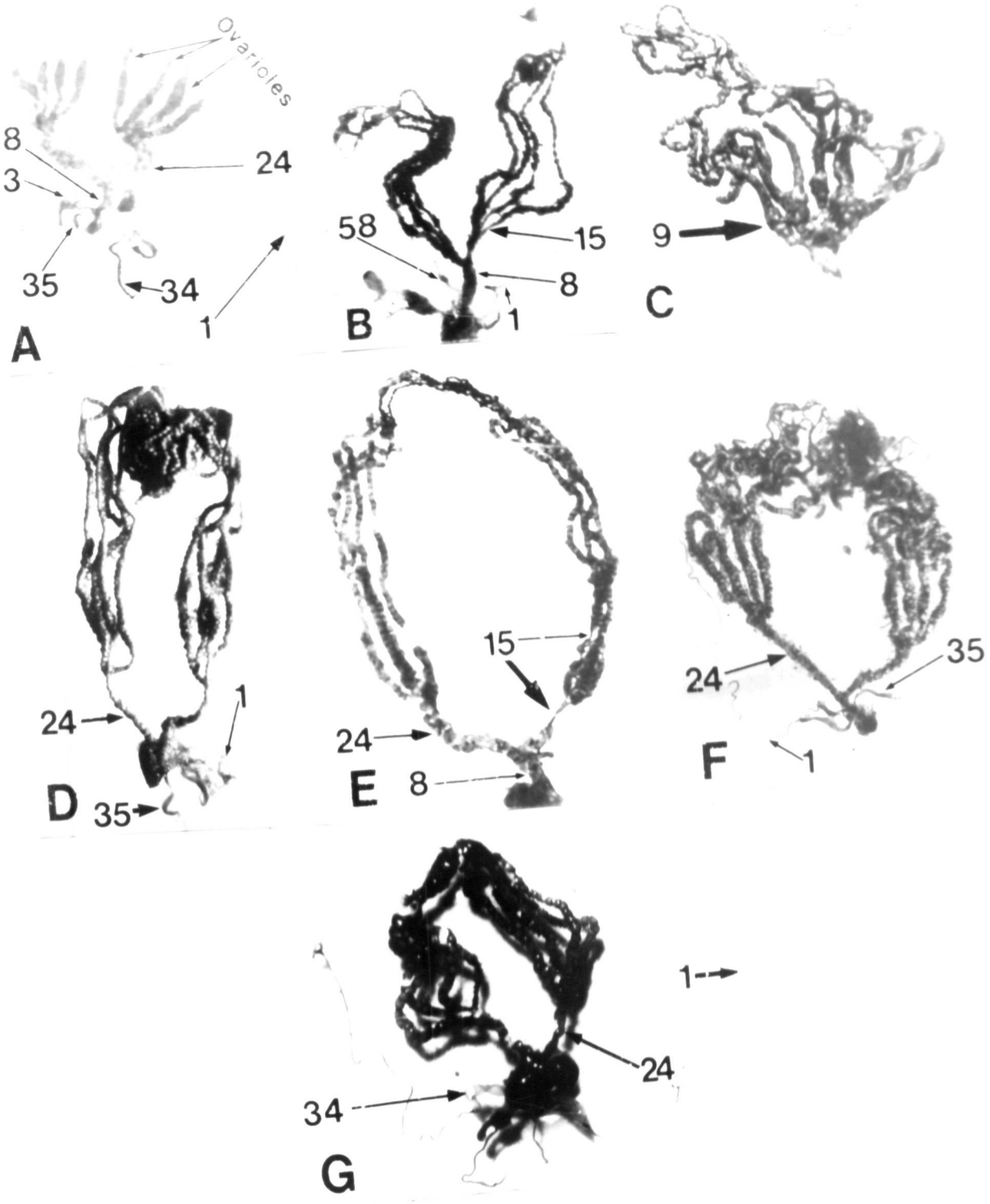
D= Whole mount of the uncoiled reproductive system of the affected female emerged from carbaryl treated 5th instar larvae.

E= Whole mount of the uncoiled reproductive system of the affected female emerged from aminocarb treated 5th instar larvae.

F= Whole mount of the uncoiled reproductive system of the affected female emerged from ethion treated 5th instar larvae.

G= Whole mount of the uncoiled reproductive system of the affected female emerged from acephate treated 5th instar larvae.

PLATE-XX


Ovarioles
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24
35
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*NOT CONSULTED IN ORIGINAL.